Ultrasonics

Part 9. Compression wave techniques

J C Drury

Calibration of timebase

The important thing to remember when calibrating the timebase for compression waves is that the left-hand end of the timebase (Zero) must exactly correspond to the entry surface of the beam and the right-hand end represents a known thickness in the material being tested. The exceptions to this rule are those occasions when you are using delay to expand some distant portion of the material, or when you are using a multiple echo technique and only noting the decay pattern. For single-crystal probes, the initial pulse contains two elements; the applied square-wave voltage pulse and the ringing of the crystal. The end of the applied voltage pulse represents the top surface at which time the crystal ringing starts. Unfortunately, the amplitude of this part of the initial pulse is so large that it is not possible to identify the point at which the ringing starts, nor is it possible to tell from the timebase line.

There is a similar problem when we calibrate using a twin-crystal probe because the initial pulse is at the start of the Perspex delay line and the sound enters the work-piece sometime later. In any case, because the amplifier is deliberately isolated from the transmitter crystal, there is no signal to mark the entry surface. Our calibration procedure, whether for a single- or twin-crystal probe must find some other way to identify the entry surface or true zero. The most common way to achieve this is to use two echoes that are a known distance apart, to set one at timebase zero and the other at the right-hand end (10) of the timebase. We do this in the following way:

- ☐ Use the delay control to position the first backwall echo from the desired range on our calibration block to zero.
- ☐ Then use the depth range controls to position the second backwall echo to 10 on the timebase.
- ☐ This may also move the echo from the zero position and so we need to check and adjust this with delay again.
- ☐ These two controls are used alternately until the two echoes are exactly on 0 and 10. We now know that the timebase is exactly equal to the calibration thickness
- ☐ Once we are happy that we have that exact range on the timebase, we lock the **depth** controls.
- ☐ We then use **delay** to move the first backwall echo to the right until it is exactly on 10. If the timebase is exactly a known range and the first backwall echo is on 10; then zero must coincide with the entry surface.

Figures 9.1 to 9.3 illustrate the procedure for calibrating the timebase for 100 mm of steel on the A2 calibration block.

In this example we know that the first and second backwall echoes represent 100 mm and 200 mm of steel path time because the A2 block is 100 mm wide at this probe position. Therefore, Figure 9.2 represents exactly 100 mm timebase. This timebase

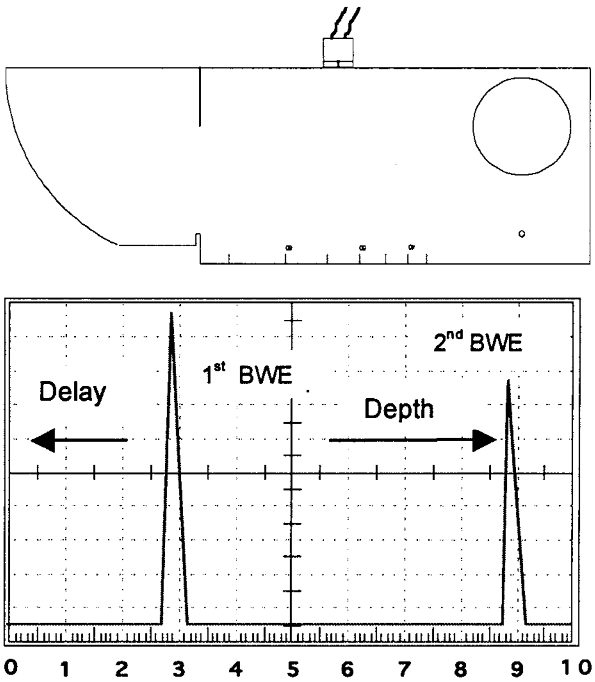


Figure 9.1

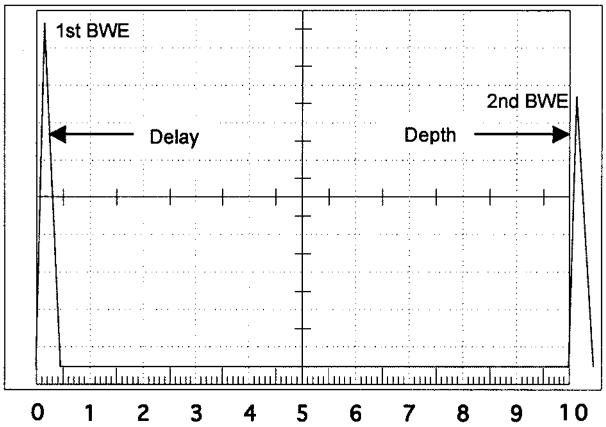


Figure 9.2

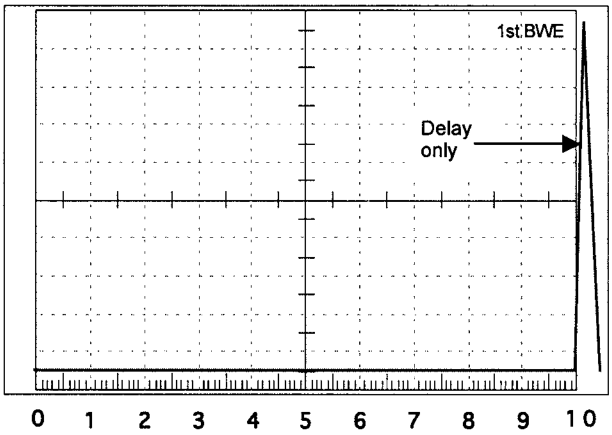


Figure 9.3

remains constant as long as we do not alter the depth control, so Figure 9.3 represents zero to 100 mm exactly.

Choice of compression wave probes

Twin-crystal probes

For conventional techniques, twin-crystal probes are generally used on thicknesses below 50 mm. They are also in general use for high-temperature thickness measurement, where a thermal insulating material is used instead of Perspex, to protect the crystals. Because the transmitter section of the probe is isolated from the amplifier, there is no dead zone and so reflections from surfaces close to the probe can be identified. However since the Perspex shoe absorbs some sound, less damping is used and the pulses are longer so that resolution is generally poorer than with single probes.

Single-crystal probes

Single-crystal probes are generally used on thicknesses in excess of 50 mm. They are also used below 50 mm if resolution is an important factor, since single-crystal probes usually have shorter pulse lengths than twin-crystal probes. However, for conventional techniques they can only be used when the transmission noise (Dead Zone) does not encroach upon the useful part of the timebase for that job. As a guide, you can expect the shortest Dead Zone from high frequency, heavily damped probes.

Probes for multiple-echo technique

These are usually single-crystal probes, although in some cases twin-crystals can be used. When dealing with thin-walled material it is possible to get resonance and anti-resonance conditions that will affect the decay pattern and may give false indications. This can be avoided if you choose a probe frequency such that the plate thickness is more than 1.5 x the wavelength of the compression wave in the specimen material, and a pulse length that is not more than three cycles.

Thickness measurement

One of the most important uses of ultrasonics is that of thickness measurement. It is particularly useful because it is relatively quick, simple and accurate, and access to only one surface of the specimen is required. There are many types of equipment and techniques made exclusively for thickness measurement. It is not intended to deal with all of them here. We will only discuss the use of the pulse echo system with an A-scan display.

A-scan rectified display

This is the most common display presentation for ultrasonic flaw detection equipment. In the sixth article we described the display for an unrectified trace and various types of rectification.

a) Calibration

The basic calibration of the timebase should be carried out to ensure proper positioning of the zero and backwall echo as described above. The calibration block should be made of the same material as the work-piece.

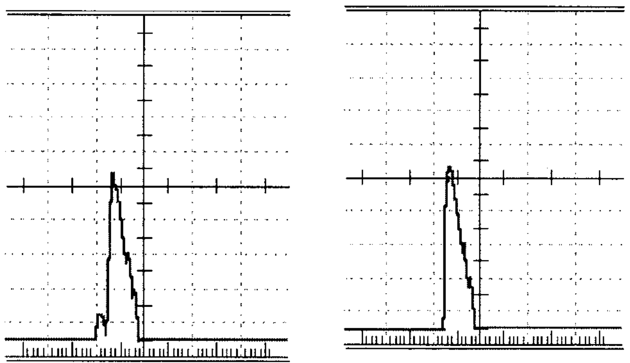
For best results the range chosen for calibration should be the shortest range which allows the first back wall echo to be displayed. For example, if the nominal wall thickness of the work-piece is 9 mm. and your flaw detector is capable of showing 10 mm across the full graticule, then the 10 mm range should be used. Since the graticule of most flaw detectors can be divided into 100 small units it follows that a timebase calibrated such that those 100 units represent 10 mm gives you a reading accuracy of 0.1 mm per division. If on the other hand you calibrate such that 100 units represent 25 mm, the reading accuracy is 0.25 mm per division.

b) Amplitude (gain setting)

The amplitude of the calibration echo and the amplitudes of thickness echoes made on the work-piece should be adjusted to the same predetermined amplitude. This is normally between ⅓ and ½ full screen heights.

c) Reading the thickness (single echo)

The specimen thickness is determined from the left-hand edge of the backwall echo. This is normally a steep sloping line. If a small half-cycle appears at the left-hand edge of the signal that was not present during calibration, this may be removed by inserting a small amount of suppression or by choosing 'positive' or 'negative' rectification (see Figure 9.4).



Extra half cycle

After suppression or rectification change

Figure 9.4

d) Reading the thickness (multiple echoes)

If the specimen thickness and calibrated range are such that multiple echoes are produced, the most accurate result can be obtained by reading the thickness of the last multiple echo displayed and dividing the answer by the number of backwall echoes. In the example shown in Figure 9.5, the fifth backwall echo shows at 22 mm, so the true thickness is *22* divided by 5 = 4.4 mm. In this case, a single-crystal probe has been used and the initial pulse is obscuring the start of the first backwall echo.

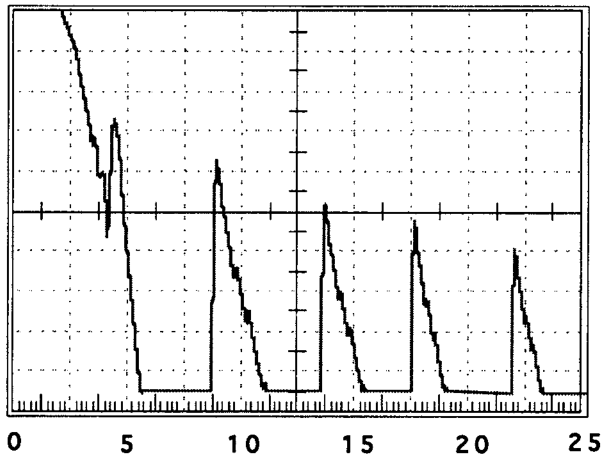


Figure 9.5

Sometimes the initial pulse obscures the entire first backwall echo and maybe all or part of other back echoes. Figure 9.6 shows the same thickness but with the first two back echoes obscured. Care must be taken to assess the number of echoes that have been obscured.

e) Use of timebase delay

Apart from its use to correct for Perspex path distance in twin crystal compression wave probes, 'Delay' can be used as an aid to more accurate thickness measurement. For example, you may

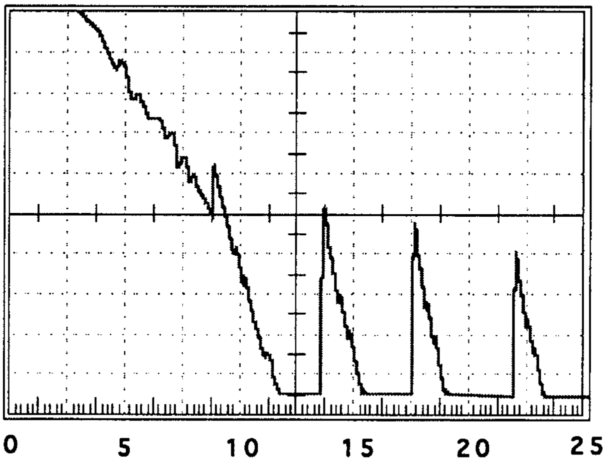


Figure 9.6

want to measure accurately the thickness of a component whose nominal thickness is 80 mm. If you calibrate the timebase so that 100 scale divisions represents 100 mm of that material, each small division represents 1 mm. If instead you calibrate the timebase so that 100 scale divisions represent 25 mm of the test material each division on the scale represents 0.25 mm instead of 1 mm. The delay control can then be adjusted so that the third backwall echo from the calibration block is set at O, and the fourth backwall echo at 100 scale divisions. The timebase would represent a thickness range of 75 mm to 100 mm. The first back echo from the work-piece (80 mm) will appear at approximately 1/5th of the timebase range.

A-scan unrectified display

There are occasions in thickness measurement, particularly if the scanning surface is rough, when a lot of unwanted signals, 'noise' or 'grass' appear on the CRT and make it difficult to determine the point at which the back echo starts. If the ultrasonic set allows an unrectified trace to be selected, then measurements can be made using the tip of a particular down going half cycle instead of using the point at which the signal first leaves the timebase.

- ☐ Firstly, let us identify our measuring point. Figure 9.7 shows a back echo from the 25 mm range on the V1 block with the timebase calibrated for 50 mm using the conventional rectified display. The presentation has then been changed to 'unrectified' and the vertical or 'Y' shift used to raise the timebase to a level between 1/3 and 175th full screen height. Gain has been adjusted so that the peak of the longest down going half-cycle just meets the graticule. In this case, it is the second half-cycle that is the longest, and we will use the second half-cycle as our measuring point. (Note that sometimes a back echo from the work-piece may show the 1st or 3rd half cycle as the longest - despite this, if you calibrate on the second half-cycle you then always measure from the second half-cycle even if it is not still the longest,*)*
- ☐ Having identified the half-cycle that you are going to use, you calibrate the timebase so that this part of the signal coincides with the correct point of the graticule. In the case shown in Figure 9.7, if we wished to calibrate for 50 mm we would use 'delay' to move the second half cycle from 5.15 to 5.0 divisions and check that the second half-cycle of the second back echo coincides with 10.0 divisions (see Figure 9.8).
- ☐ Calibration for other timebase ranges would be done in the conventional way but using the second half cycle instead of the left hand edge of the pulse, as your measuring point.

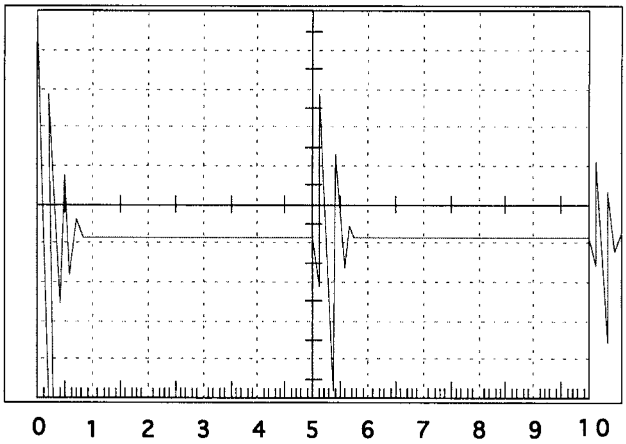


Figure 9.7

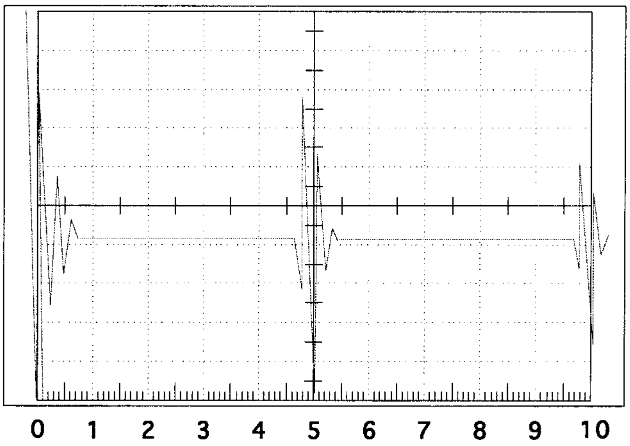


Figure 9.8

Lamination testing

Lamination testing of plates and pipes that are to be welded or machined is a very common NDT task. It is also a simple application of compression waves in ultrasonic flaw detection, but one that might give some problems when examining thinner samples.

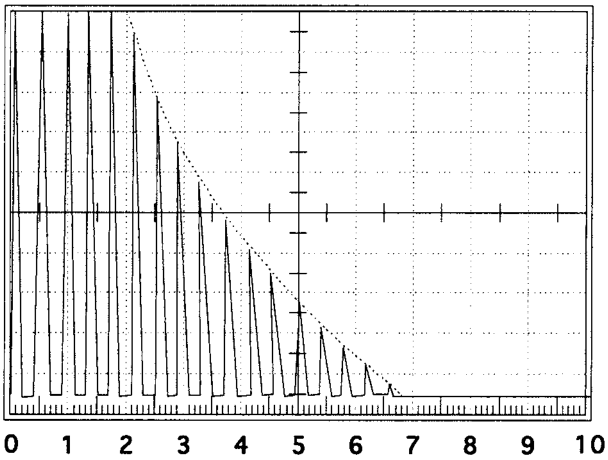
Standard procedure

- ☐ Calibrate the timebase to allow at least two backwall echoes to be displayed.
- ☐ Place probe on the work-piece and adjust the gain controls so that the second backwall echo is at full screen height.
- ☐ Scan the work-piece looking for lamination indications that will generally show up near half-specimen thickness together with a reduction in back echo amplitude. In some cases, a reduction in the amplitude of the second back echo may be noticed without a lamination signal being present. Care must be taken to ensure that this reduction in amplitude is not due to poor couplant or surface conditions.

Multiple echo technique

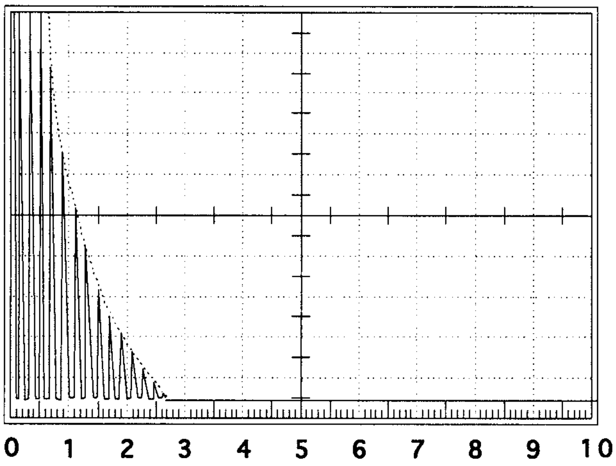
Lamination testing of plate or pipe less than 10 mm in wall thickness may be difficult using the standard procedure because multiple echoes are so close together that it becomes impossible to pick out lamination signals between backwall echoes. In such cases, we can use a technique called the 'multiple echo technique' using a single-crystal compression wave probe. The procedure is as follows:

- ☐ Place the probe on a lamination free portion of the work or calibration piece.
- ☐ Adjust the timebase and gain controls to obtain a considerable number of multiple echoes in a decay pattern over the first half of the time base. A typical example is shown in Figure 9.9.
- ☐ Scan the work-piece, the presence of laminations will be indicated by a collapse of the decay pattern such as the one shown in Figure 9.10. The collapse occurs because each of the



Unlaminated plate

Figure 9.9



Laminated plate

Figure 9.10

many multiple echoes is closer to its neighbour in the presence of a lamination.

Examination of brazed and bonded joints

Compression waves can also be used for the detection of areas of non-adhesion in brazed or bonded (glued) joints,

a) Brazed joints

If the wall thicknesses permit clear separation between backwall echoes, brazed joints can be examined using the standard procedure for lamination checking. However, since the braze metal separating the two brazed walls will have a slightly different acoustic impedance to that of the parent metal, a small interface echo may be present for a good braze. The technique, therefore, is to look for an increase in this interface echo amplitude. Figure 9.11 shows the type of indication when the unbrazed portion is smaller than the beam diameter. If the two brazed walls are too thin to permit clear back echoes, a multiple echo technique can be used as described above.

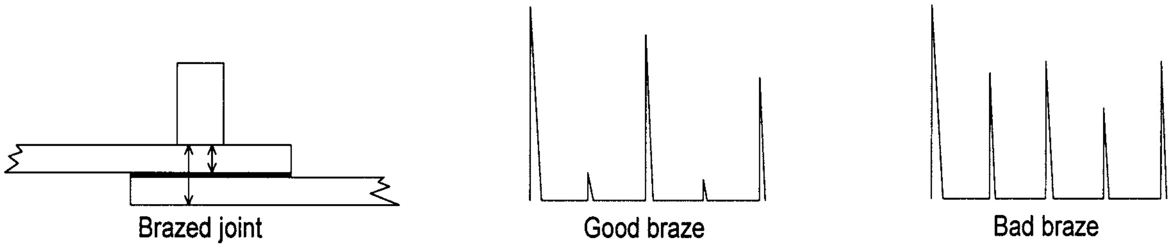
b) Bonded joints

These may include metal-to-metal glued joints and metal to non-metal glued joints (for example rubber blocks bonded to steel plates). The technique used is a multiple-echo technique. Each time the pulse reaches a bonded interface, a portion of the energy will be transmitted into the bonded layer and absorbed. Each time a pulse reaches an unbonded layer, all the energy will be reflected. If we look at the multiple echo pattern for a good bond, the decay will be relatively short because of the energy loss at each multiple echo into the bond. However, for an unbonded layer each multiple echo will be slightly bigger because there is no interface loss, and the decay pattern will be significantly longer. Figure 9.12 shows a good bond (probe 1) and poor bond (probe 2).

References

'Ultrasonic Flaw Detection for Technicians' - Third Edition, June 2004 by J C Drury.

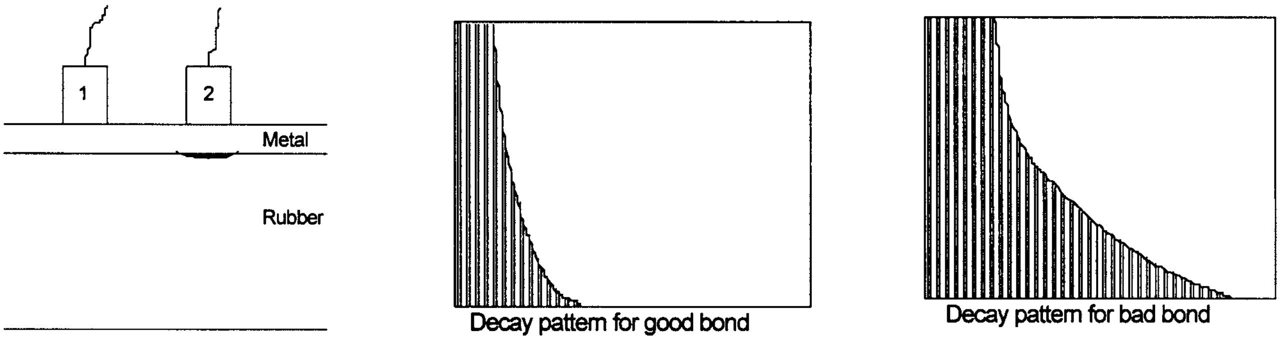
The next article in this series will deal with shear wave techniques.


Brazed joint

Good braze

Bad braze

Figure 9.11



Decay pattern for good bond

Decay pattern for bad bond

Figure 9.12

Ultrasonic Flaw Detection for Technicians, 3rd Edition

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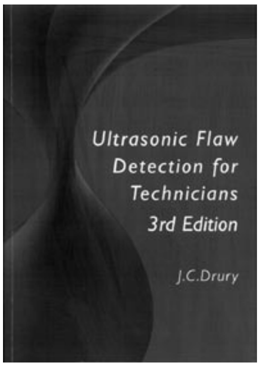

In the twenty-five years since the first edition of 'Ultrasonic Flaw Detection for Technicians' was published, there have been a number of advances in transducer technology and flaw detection instruments. The gradual acceptance by industry that the sizing of weld defects by intensity drop was not as accurate as had been claimed led to the development of the TOFD technique. Modern digital flaw detectors and computer technology allow far more information to be stored by the operator. The author thus felt that it was time to give the book a thorough review and to try to address some of the advances. The result is this new edition.

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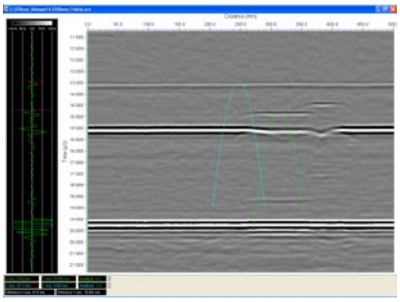

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