4. Precautions

a) A dual-channel digital storage oscilloscope of bandwidth minimum 20 MHz is required.

b) The original probes of the oscilloscope should be used to prevent waveform distortion.

c) When performing measurement in air, an acoustic coupling agent such as cream or oil should be applied between the ultrasonic probe and the object under test.

d) Apparatus should be grounded properly.

e) Due to the existence of high voltage (380 V) at ultrasonic probe, care must be taken when plugging or unplugging the BNC cable between the ultrasonic probe and the main unit.

e) After experiment, samples should be stored in the accessory box.

5. Experimental Contents

a) Measure sound velocity in water or the thickness of a water layer
b) Measure sound velocity in solid material
c) Ultrasonic diagnosis
d) Determine the resolution of apparatus for aluminum alloy material
e) Nondestructive detection using ultrasonic pulse-echo method

6. Experimental Procedure

1) Preparation:

Mount the ultrasonic probe on the side of the water tank and fill clean water into the tank till the water surface is above the probe by 1 cm. Since water is a good coupling agent, the following experiments are all conducted in the water.

Connect the probe to the "Probe" terminal on the main unit; connect "Signal Output" of the main unit to the oscilloscope using a BNC cable; set oscilloscope input mode at "AC", use the rising edge trigger mode, and find a proper trigger level to get a stable waveform.

2) Mount a cylindrical sample on the sample holder; place the holder onto the rail and adjust the holder orientation to maximize the reflection signal.

Move the holder to different positions in water while measuring the propagation time from ultrasound wave emitted from the probe to that reflected back by the first surface of the sample. Take one point every 2 cm.

Conduct $X \sim t/2$ linear fitting to the data, and then calculate sound velocity in water. **Note**: the echo signal reflected from the tank wall may be observed, which should be discarded.

3) To measure the propagation velocity of ultrasonic wave in a solid sample, first mount the cylindrical sample on the sample holder; and then place the holder onto the rail while adjusting the holder to maximize the reflection signal.

Measure the time difference between the two echo signals reflected from the front and the back surfaces of the sample, t_2-t_1; and sample length d to calculate sound velocity in the sample.

4) Ultrasound diagnosis of simulated human organ:

Refer to Figure 6, place Sample 1 at a small distance from the probe as a simulated abdominal wall and place Sample 2 at a certain distance from Samples 1 as a simulated human organ in the abdominal cavity. Note: multi-reflection echo signals between the two samples and internal surfaces of each sample should be discriminated. Since plastic glasses have large attenuation to ultrasound, it is better to use crown glass or aluminum alloy samples.

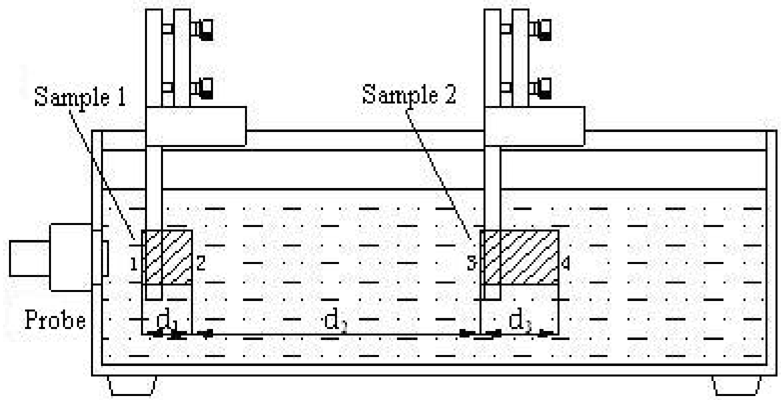

Figure 6 Simulation of ultrasound diagnosis of human organ

5) Measurement of resolution:

Fix the resolution sample beneath the horizontal slider using the two screws and place it in the middle of the horizontal rail, so that the ultrasonic probe can detect the reflected echo signals of different sound path lengths from the left and right of the stairs on the back surface through the front surface.

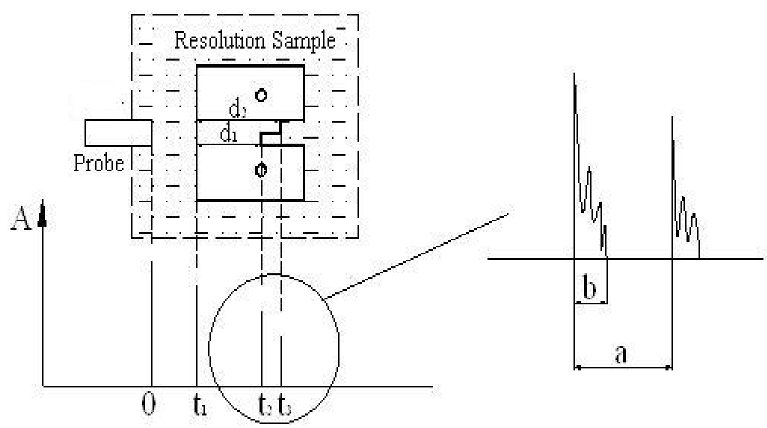

Figure 7 Schematic of measurement of resolution

Refer to Figure 7, by measuring d_1, and d_2 while reading a and b values from the oscilloscope, the resolution of the apparatus corresponding to this specific medium can be calculated as:

$$F = (d_2 - d_1)\frac{b}{a} \tag{4}$$

6) Flaw detection using ultrasonic pulse reflection method:

An aluminum alloy work piece is provided, which has two thin slits of different depths as seen in Figure 8 for flaw detection using ultrasonic pulse reflection method.

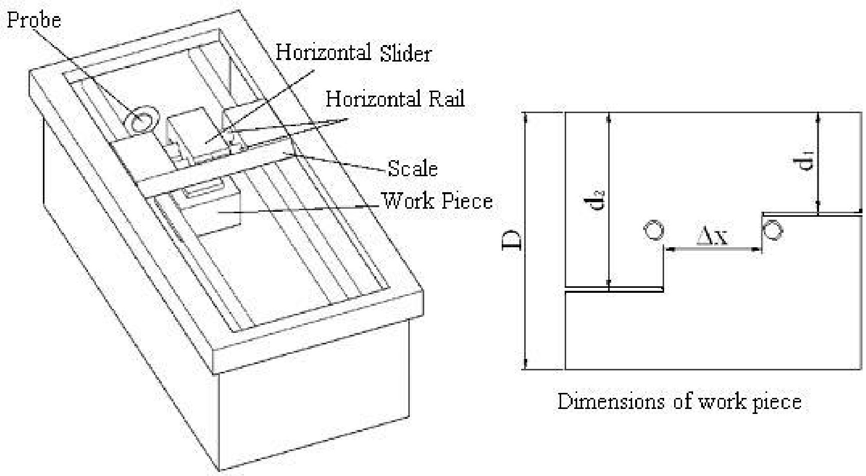

Figure 8 Schematic of flaw detection using ultrasonic pulse reflection method

7. An Example for Data Recording and Processing

Note: Data is only for reference purpose, not the criteria for apparatus performance.

A. <u>Measurement of sound velocity in water</u>

Table 1 Propagation time of ultrasound reflected by the first surface of the sample in water (room temperature T=16.0 °C)

X (cm)	4.99	7.00	8.98	11.10	13.02	15.08
t (μs)	56.0	83.2	110.4	139.2	165.6	194.4
t/2 (μs)	28.0	41.6	55.2	69.6	82.8	97.2
X (cm)	17.00	19.01	20.95	23.00	25.01	27.11
t (μs)	220.8	248.0	274.4	303.2	332.0	357.6
t/2 (μs)	110.4	124.0	137.2	151.6	166.0	178.8

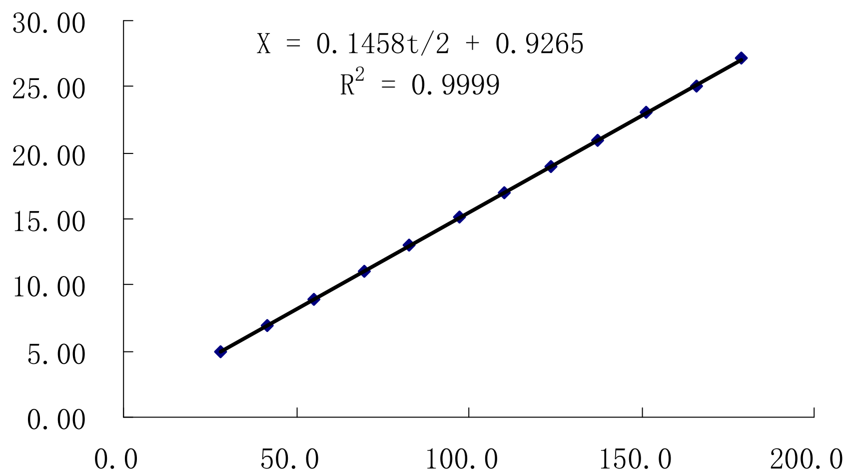

Figure 9 Plot of X~$t/2$

The slope of the fitted line is the ultrasonic propagation velocity in water, 0.1458 cm/μs, or 1458 m/s. The recognized value of ultrasonic velocity in water at 16 °C is 1464 m/s, leading to a measurement error of less than 1%.

B. Measurement of sound velocity in crown glass samples

Table 2 Ultrasound propagation time reflected from the front and back surfaces of crown glass sample

d (mm)	24.96			50.07		
t_2 (μs)	48.16	59.76	76.40	84.56	103.68	132.64
t_1 (μs)	56.64	68.24	84.88	101.48	120.64	149.60
$(t_2-t_1)/2$ (μs)	4.24	4.24	4.24	8.46	8.48	8.48
V_{glass} (mm/μs)	5.887	5.887	5.887	5.918	5.904	5.904
$\overline{V_{glass}}$ (mm/μs)	5.898					

Sound velocity in crown glass is calculated as 5.898 mm/μs， i.e. 5898 m/s.

C. Ultrasound diagnosis

The short aluminum alloy cylindrical sample (d_1=24.97 mm) is used to simulate the abdominal wall, and the short crown glass cylindrical sample (d_3=24.96 mm) is used to simulate the organ wall. The distance difference of the two samples from the probe is X_2-X_1=85.1 mm, so $d_2=X_2-X_1-d_1$=60.1 mm.

From the oscilloscope, we get t_1=9.84 μs for the first reflection surface, t_2=17.92 μs for the second reflection surface, t_3=101.04 μs for the third reflection surface, and t_4=108.96 μs for the fourth reflection surface. As sound velocities are known in aluminum alloy, water, and crown glass as $V_{Al}=u_1$=6250 m/s, $V_{Water}=u_2$=1464 m/s and $V_{Glass}=u_3$=5898 m/s, respectively, d_1, d_2, and d_3 can be calculated from equations (1)~(3) as 25.3 mm, 61.1 mm, and 25.0 mm, respectively. Compared with actual values, the measurement errors are less than 3%.

D. Apparatus resolution on aluminum alloy material

From the measured data: d_1=29.97 mm, d_2=38.96 mm, a=2.8 μs, and b=1.2 μs, the resolution of the apparatus is calculated as F=3.9 mm for aluminum alloy material.

E. Nondestructive detection using ultrasonic pulse-echo method

The thickness of the test work piece is D=65.2 mm, while the lengths of the first/second slits from the front surface are d_1=25.1 mm and d_2=45.1 mm, respectively. The spacing between the edges of the two slits in direction perpendicular to the propagation direction of ultrasonic wave is Δx=25.1 mm.

When the horizontal slider is located at x_0=84.9 mm, and there is no echo signal from defects, The time difference of the echo signals from the front and the back surfaces of the sample is $\Delta t_0=t_2-t_1$=20.48 μs; when the horizontal slider is located at x_1=72.4 mm as the ultrasonic probe is at the edge of the first slit (half-height method), the time difference of the echo signals from the front surface of the sample and from the first slit is $\Delta t_1=t'_1-t_1$=7.84 μs and the depth of this defect is calculated as: $d'_1=D\Delta t_1/\Delta t_0$=24.5 mm; when the horizontal slider is located at x_2=97.2 mm while the ultrasonic probe is at the edge of the second slit (half-height method), the time difference of the echo signals from the front surface of the sample and from the second slit is $\Delta t_2=t'_2-t_2$=14.24 μs and the depth of this defect is calculated as: $d'_2=D\Delta t_2/\Delta t_0$=45.3 mm.

Finally, the spacing between the edges of the two slits is $\Delta x'=x_2-x_1$=24.8 mm by using the half-height method.