Ultrasonic echography (B-Scan)

Physics	Acoustics	Ultrasounds

Biology	Modern Imaging Methods in Biology

Applied Science	Engineering	Non Destructive Testing (NDA)	Ultrasound examination
			Applied Science

Medicine	Radiology & Ultrasonic Diagnostics	Ultrasonic Imaging

Difficulty level	Group size	Preparation time	Execution time
hard	2	10 minutes	45+ minutes

This content can also be found online at:

http://localhost:1337/c/5f0ed55ab6127b000304499f
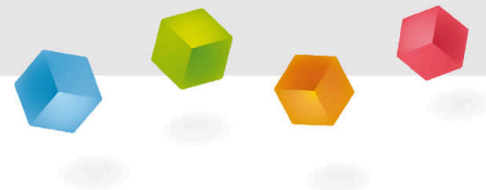
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General information

Application

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Fig. 1: Equipment for ultrasonic echography, experimental set-up

B-scan ultrasonography is an important adjuvant for the clinical assessment of various ocular and orbital diseases. With understanding of the indications for ultrasonography and proper examination technique, one can gather a vast amount of information not possible with clinical examination alone.

Other information (1/3)   **PHYWE**

Prior knowledge

Ultrasound are sound waves with frequencies which are higher than those audible to humans (>20,000 Hz). Ultrasonic images, also known as sonograms, are made by sending pulses of ultrasound into tissue using a probe. The ultrasound pulses echo off tissues with different reflection properties and are recorded and displayed as an image.

Scientific principle

The fundamental principles concerning the generation of ultrasonic B-scan images (brightness representation of the reflection amplitudes) are demonstrated with the aid of a simple test object. The experiment is executed with an ultrasonic echoscope in the pulse-echo-mode and the object is scanned manually. Then, the image quality and the most important image defects are assessed.

Other information (2/3)   **PHYWE**

Learning objective

To learn about Propagation of ultrasonic waves, Time of flight, Echo amplitude, Reflection coefficient, A-scan, Flaw detection, Non destructive testing (NDT), Ultrasonic transceiver

Note

Pay attention to the special operation and safety instructions in the manual of the ultrasonic echoscope.

Other information (3/3)

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Tasks

1. Measure the 3 edge lengths of the test block with a vernier calliper and determine the time of flight of the sound for the various edge lengths of the test block with the aid of the measurement software.

2. Calculate the sound velocity of the test block material and switch the measurement software (A-scan mode) to depth measurement.

3. Produce two B-scans, one with the 1 MHz probe and one with the 2 MHz probe, with the aid of the measurement software (B-scan mode).

4. Measure the depth and width of the echoes in the resulting images.

5. Characterise the quality of the images in terms of their resolution and defects.

Safety instructions

- For this experiment the general instructions for safe experimentation in science lessons apply.

- Read the supplied operating instructions thoroughly and completely prior to starting the unit. Ensure that all of the safety instructions that are listed in the operating instructions are strictly followed when starting the unit.

- Only use the unit for its intended purpose.

- Pregnant women as well as people with cardiac pacemakers must keep a distance of at least 1 m from the magnet.

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Theory (1/4)

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The known length (s) of a material and the measured time of flight (t) of the ultrasound wave can be used to determine the sound velocity (c) with the aid of equation (1):

(1) $c = \frac{2s}{t}$ (double length in the case of reflection measurements)

Most ultrasonic probes have a coupling and protective layer (matching layer) in front of the piezoceramic element. This layer leads to a measurement error during the determination of the sound velocity. This means that the measured time of flight (t) includes the time of flight in the coupling layer t_L as well as in the sample t_S

This error can be eliminated by using the difference between two measurements of the same material with different lengths s_1 and s_2 (equation (2)).

Theory (2/4) PHYWE

$$(2)\ c = \frac{2(s_1 - s_2)}{t_1 - t_2} = \frac{2(s_1 - s_2)}{(t_{s_1} + t_L) - (t_{s_2} + t_L)} = \frac{2(s_1 - s_2)}{t_{s_1} - t_{s_2}}$$

In a sectional ultrasound image (B-scan), the echo amplitude is displayed as a greyscale value and the time of flight as the penetration depth. A string of several adjacent depth lines leads to the sectional image. For this purpose, the probe must be moved lengthwise over the area of examination. The local resolution along this scanning line results from the position of the probe or its speed of movement. A simple way to produce a sectional image is to move the probe slowly by hand (compound scan). However, in this case, a precise lateral resolution is only possible with the aid of additional coordinate acquisition systems, such as linear scanners. On the other hand, thanks to the low scanning speed, high-quality images can be produced over extended examination areas.

Theory (3/4) PHYWE

The image quality is determined by the following parameters:

- Precise, coordinate-based image point transmission (scanner system)

- Axial resolution (ultrasound frequency)

- Lateral resolution (sound frequency, sound field geometry, and focus)

- Greyscale resolution (transmission power, gain, and TGC)

- Number of lines (scanning speed)

- Aberrations (acoustic shadows, multiple reflections, and movement artefacts).

Equipment

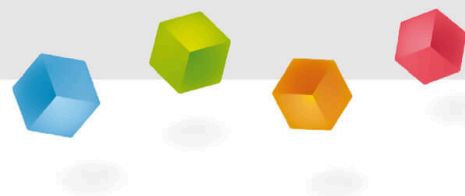| Position	Material	Item No.	Quantity
1	Basic Set Ultrasonic Echography II	13924-99	1
2	Vernier calliper stainless steel 0-160 mm, 1/20	03010-00	1
3	Ruler, plastic, 200 mm	09937-01	1

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Setup and procedure

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Setup and Procedure (1/14)

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The system Basic Set "Basic Set Ultrasonic echoscope II " consists of an ultrasonic echoscope controller which connects to a computer via USB interface, ultrasonic probes (1 MHz and 2 MHz), an ultrasonic test block, an ultrasonic cylinder set, ultrasonic text plates, ultrasonic gel and echoscopy software for Windows.

Figure 1 shows the experiment set-up.

Ultrasound test block:

The following illustration (Fig. 2) shows the technical drawing of the ultrasound test block with its nominal dimensions.

For easier communication, in figure 3 numbers for the individual flaws (holes) and terms for the measurement distances are indicated:
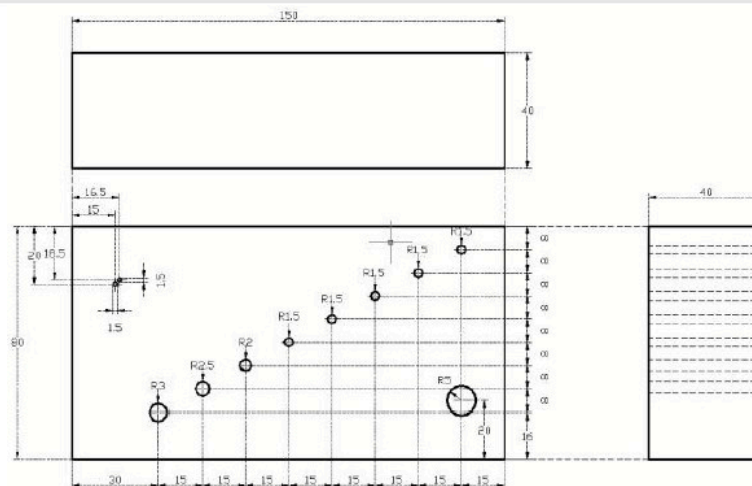
Setup and Procedure (2/14)

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Fig. 2: Dimensional drawing of the ultrasound test block
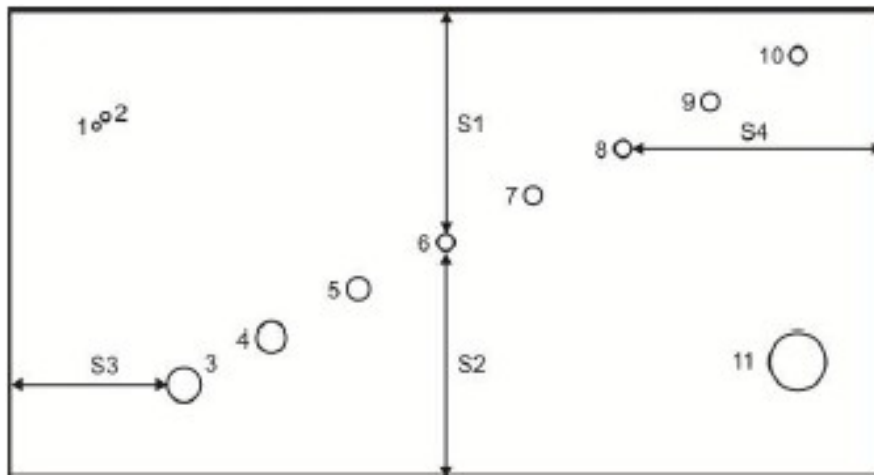
Setup and Procedure (3/14)

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Fig. 3: Names of the flaws (holes) and measurement distances

Setup and Procedure (4/14)

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Advice concerning applying ultrasound gel:

Although ultrasound gel is very effective in this experiment, we recommend using water instead because it is easier to handle during the experiment and remove after the experiment. Apply   a water film to the surface of the text block to couple the ultrasonic probes to the test block. This is even usefull for producing a scan (i.e. if the probe must be moved steadily over the block surface).

Caution: If you prefer to work with ultrasound gel, wipe the ultrasound test block and the ultrasonic probes clean immediately after they have been used in combination with ultrasound gel. Then, clean them with water or a soap solution. Do not use alcohol or liquids with solvents for cleaning the equipment. Avoid any mechanical damage to the surface (scratches etc.) since it would have a negative effect on the sound contact.

Please proceed as follows:

Setup and Procedure (5/14)

Connecting the equipment

Connect the ultrasonic echoscope to a free USB port of your computer with the aid of a USB cable. If the software has been installed correctly, the device will be automatically identified.

Connect the ultrasonic probes (1 MHz or 2 MHz) to the "Reflec." input. For pulse-echo-measurements, the selector switch must be set to "Reflec.".

Apply a thin water film to the block in order to couple the ultrasonic probes to the block.

Caution: Do not use too much water for coupling since it might flow under the block and change the reflection signal of the bottom echo (sound will be coupled out to the surface underneath the block (table).

Setup and Procedure (6/14)

Software

The software is used for recording, displaying, and evaluating the data. After the start of the software, the device and interface will be identified automatically. The main screen with the A-scan signal in the upper area and the TGC in the lower area will be displayed. The frequency of the receiver probe and the device settings (gain, transmitting power, reflection/transmission) will also be displayed. The measurement cursors can be moved with the mouse, and the amplitude and time of flight can then be read. All of the other settings can be reached via the menu or with the aid of buttons in the program interface.

Caution: Please observe the special operating and safety instructions in the instruction manuals of the ultrasonic echoscope.

Setup and Procedure (7/14)

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Performing the experiment

In order to determine the sound velocity of the block material, the lengths of all of the edges must be measured with the vernier calliper. Then, couple the ultrasonic probe to the block with the aid of some water or ultrasound gel. Do this in a place with as few flaws (holes) as possible. Determine the time of flight up to the opposite surface of the object in the A-scan mode. Set the gain, including TGC and the transmitting power, so that the echo can be detected without problems (see Fig. 4-6). At greater distances, a higher gain must be selected because of the strong attenuation. During the measurement of the long side, the A-scan will always include the echoes of the holes (Fig. 6). The bottom echo (reflection at the opposite side) can be easily identified by moving the probe since it maintains its position in the A-scan.
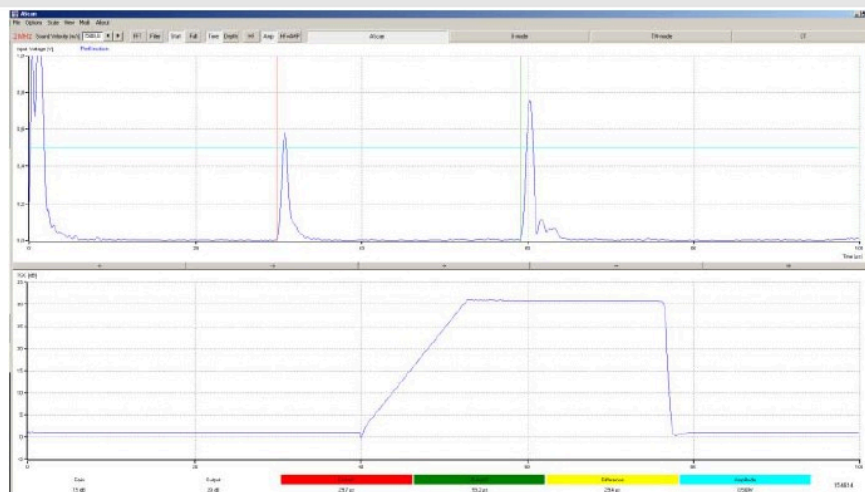
Setup and Procedure (8/14)

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Fig. 4: Side 1 with an edge length of approximately 40 mm
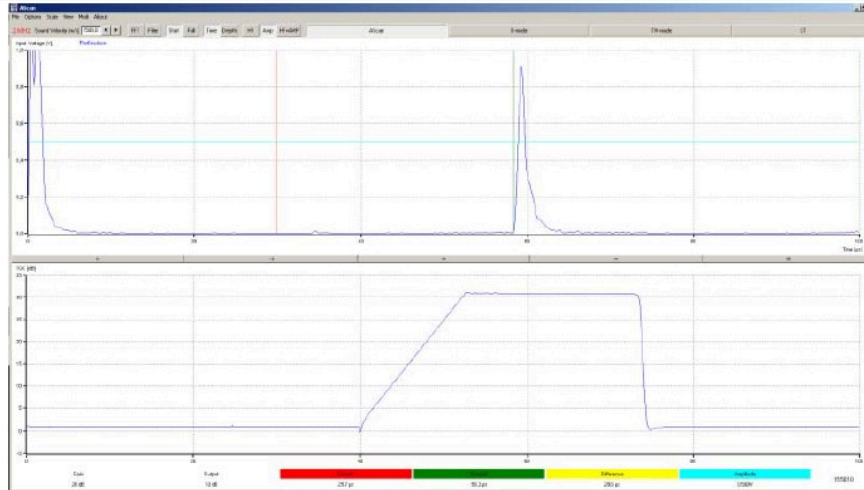
Setup and Procedure (9/14)

PHYWE

Fig. 5: Side 2 with an edge length of approximately 80 mm
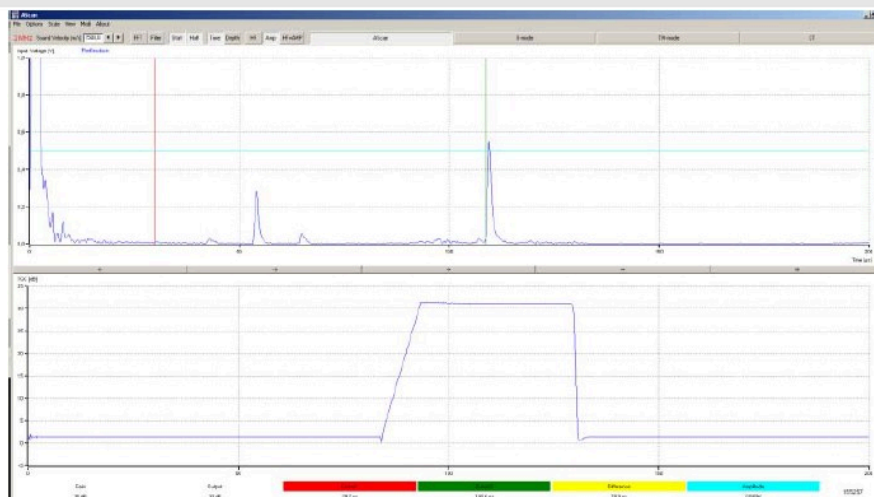
Setup and Procedure (10/14)

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Fig. 6: Side 3 with an edge length of approximately 150 mm

Setup and Procedure (11/14)

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The times of flight and the edge lengths can be used in combination with equation (1) in order to determine the sound velocity of the test block material.

Enter this value into the field "Sound Velocity" and switch the software to the depth measurement ("Depth"). The transmission and reception settings of the echoscope must be selected so that the signal amplitude does not overshoot even in the case of objects that are located close to the surface. For this purpose, the TGC settings must be varied (see Fig. 7).

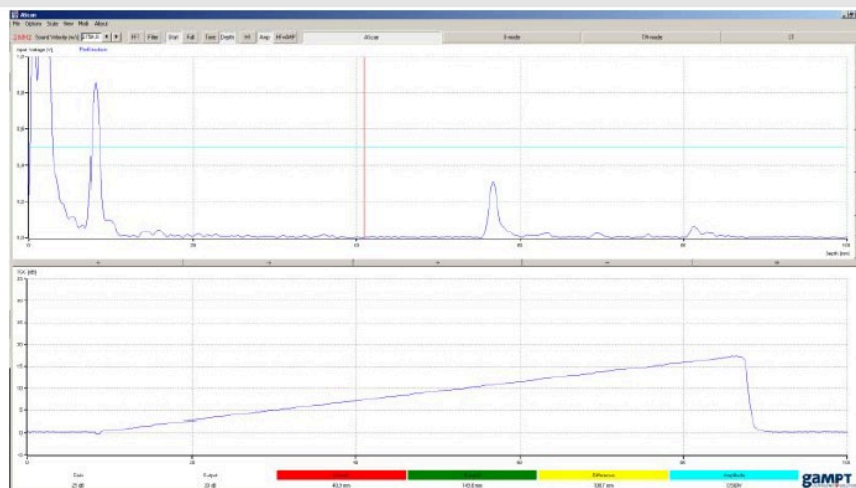# Setup and Procedure (12/14)

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Fig. 7: Settings of the software in the A-scan mode for the manual recording of a B-scan

Setup and Procedure (13/14)   **PHYWE**

Then, press the "B-Mode" button in order to start the software for recording a 2D brightness image (B-scan, brightness).

Place the block on its long side and couple the 1 MHz probe with a water film to one of the edges of the block. Now, apply a thin water film along the entire surface of the block. Press the "Start" button in the software and move the probe steadily over the block.

When the other end of the block is reached, stop the software ("Stop" button). The contrast and brightness of the recorded B-scan image can be changed with the aid of the image processing features. The distance between the holes and the upper edge can be measured in the image with the aid of the cursor (computer mouse).

Repeat the measurement with the 2 MHz probe and compare the quality of the images.
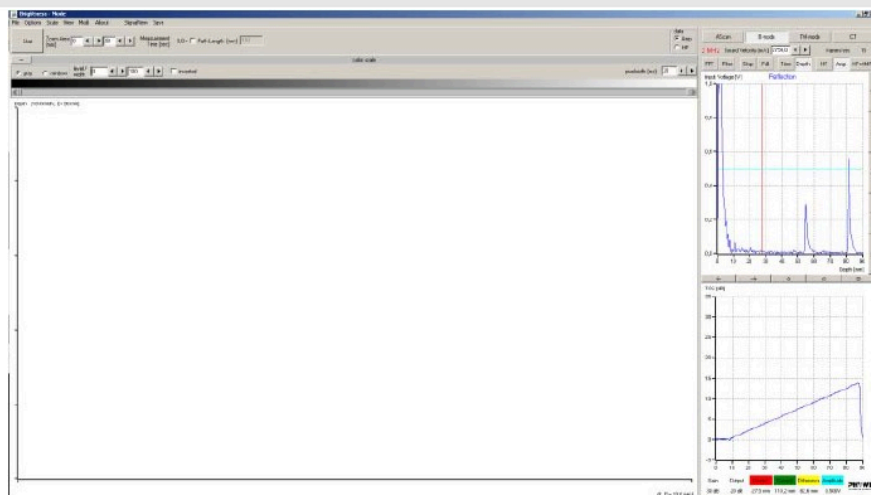
Setup and Procedure (14/14)   **PHYWE**

Fig. 8: B-mode screen prior to the start of the measurement (with current A-scan & TGC on right-hand side)

Evaluation (1/12)

PHYWE

Results

Table 1 shows the edge lengths that were measured with the vernier calliper and the times of flight that were measured with the echoscope (Fig. 4-6).

With these values, equation (2) can be used to determine the sound velocity of the material.

Based on these calculations, the sound velocity of the acrylic glass block is 2,754 m/s and this value is taken into consideration in the B-scan. As a result, it is possible to measure the holes directly in the image with the aid of the cursor. Table 3 shows the distances that were measured in the B-scan compared to the values measured with the aid of the vernier calliper.

Evaluation (2/12)

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	Length	Time of flight
	[mm]	[µs]
s_1	40.6	29.5
s_2	80.0	58.4
s_3	149.2	108.9

Table 1: Edge lengths of the test objects and times of flight

Evaluation (3/12)

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Measurement	Sound velocity
	[m/s]
$s_2 - s_1$	2,755
$s_3 - s_1$	2,753
Average	2,754

Table 2: Sound velocity of the test object

Evaluation (4/12)

PHYWE

Based on these calculations, the sound velocity of the acrylic glass block is 2,754 m/s and this value is taken into consideration in the B-scan. As a result, it is possible to measure the holes directly in the image with the aid of the cursor. Table 3 shows the distances that were measured in the B-scan compared to the values measured with the aid of the vernier calliper.

The measurement with the vernier calliper is performed directly at the upper edge of the hole. This point is too small for the ultrasound wave so that a medium signal of the hole surface is measured. The axial resolution that has been improved with the frequency is clearly visible. The 2 MHz values are much closer to the values that were determined with the vernier calliper.

The compound scanning method enables the representation of the test object with a high image quality. Since the probe is moved by hand, movement artefacts are the biggest problem in terms of the lateral resolution. Figures 9 and 10 show the B-scan images that were produced with 1 MHz probe and with the 2 MHz probe, respectively.

Evaluation (5/12)

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Hole	1	2	3	4	5	6	7	8	9	10	11
Depth (2 MHz) in mm	20.5	18.8	62.2	54.7	47.1	39.6	31.7	23.5	15.5	7.8	56
Depth (1 MHz) in mm	-	19.9	62.9	55.3	48	40.5	32.6	24.4	16.4	8.9	57.1
Vernier calliper in mm	19.3	17.5	60.8	53.5	45.9	38.3	30.4	22.3	14.3	6.3	54.8

Table 3: Distances measured in the B-scan

Evaluation (6/12)

PHYWE

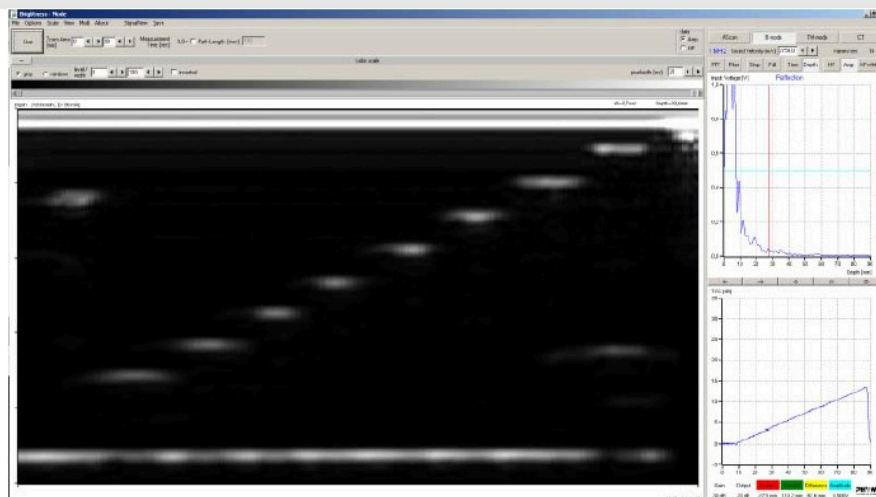

Fig. 9: B-scan image produced with the 1 MHz probe, measuring time 10 seconds, image not processed
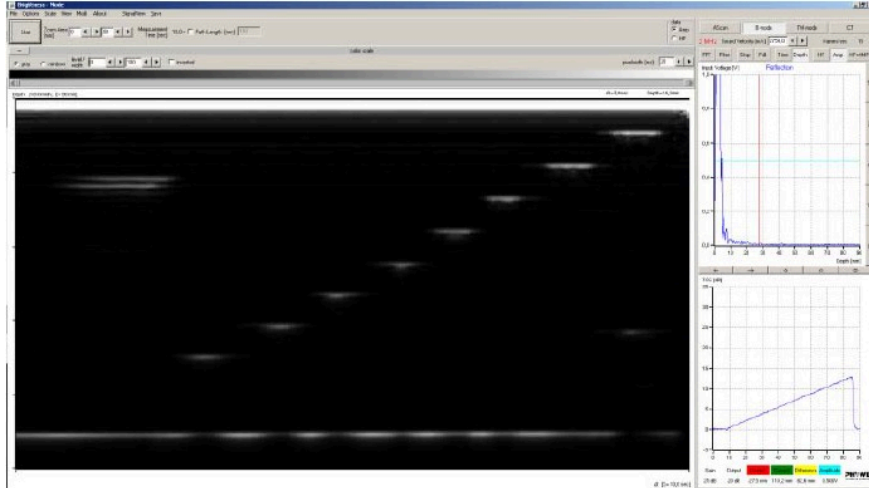
Evaluation (7/12)

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Fig. 10: B-scan image produced with the 2 MHz probe, measuring time 10 seconds, image not processed

Evaluation (8/12)

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Of the upper 5 holes of the inclined group (hole diameter: 3 mm), the third hole from the top (hole no. 8) is displayed with the best lateral resolution since the zone of focus of the 1 MHz probe lies approximately at 2.3 cm. The zone of focus of the 2 MHz probe lies a bit deeper so that, in this case, the highest lateral resolution can be found at the fifth hole from the top (hole no. 6). Table 3 shows several values for estimating the zone of focus in accordance with equation (3).

The two small holes can only be distinguished with the 2 MHz probe since it has a considerably higher axial resolution.

Evaluation (9/12)

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Probe	Radius	Frequency	Sound velocity	Wavelength	Zone of focus
	[mm]	[MHz]	[m/s]	[mm]	[cm]
1 MHz	8	1	2,754	2.75	2.3
2 MHz	8	2	2,754	1.38	4.6

Table 4: Zone of focus of the probes

Evaluation (10/12)

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The bright bottom echo is interrupted by several darker sections since the flaws that are located above it cast an acoustic shadow. Measurements particularly under the big flaw in the lower right-hand corner are no longer possible since this area remains free from sound.

Fig. 11 shows the B-scan image with modified contrast settings. The same result would be provided by an overdriven amplifier. The hole that is closest to the surface (hole no. 10) can no longer be discerned in the initial echo of the probe.

In the case of the manual scan, the steadiness of the movement plays an important role. This method is susceptible to lateral resolution and general measuring errors. Figure 12 shows a measurement that was performed with irregular scanning speed. The representation of the distances between the holes on the right-hand side is incorrect.
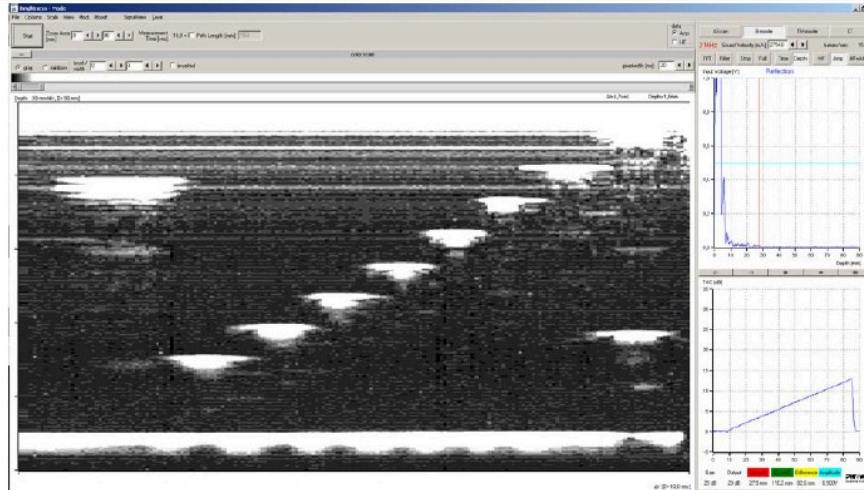
Evaluation (11/12)

PHYWE

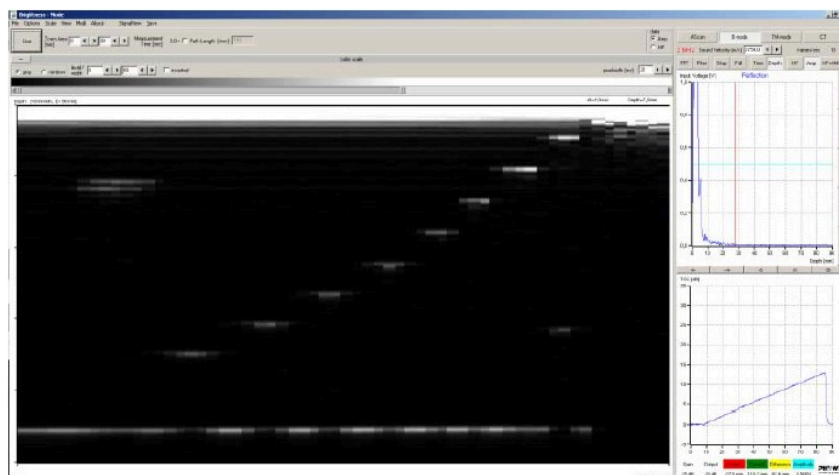Fig. 11: B-scan image with a strongly overshooting signal

Evaluation (12/12)

PHYWE

Fig. 12: B-scan image produced with irregular probe movement

Evaluation (11/11)

PHYWE

Fill in the missing words

In a sectional ultrasound image (B-scan), the ⬚ ⬚ is displayed as a greyscale value and the time of flight as the ⬚ ⬚ . A string of several adjacent depth lines leads to the sectional image. For this purpose, the probe must be moved ⬚ over the area of examination. The local ⬚ along this scanning line results from the position of the probe or its speed of movement

✔ Check