UNIWERSYTET ŚLĄSKI
WYDZIAŁ NAUK ŚCISŁYCH I TECHNICZNYCH

II PHYSICS LABORATORY

EXERCISE

Investigation of Solid Bodies Using Ultrasound

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MechBio- Innowacyjne Nauczanie Problemowe i Technologie dla Poprawy jakości Kształcenia w obszarze GZM został dofinansowany przez Górnośląsko-Zagłębiowską Metropolię w ramach Programu „Metropolitalny Fundusz Wspierania Nauki”

I. Introduction

1. Aim of the exercise

The aim of the exercise is to become acquainted with modern techniques for investigating solid bodies using ultrasonic waves.

2. Introduction to the subject

Ultrasound consists of acoustic waves with frequencies higher than the upper limit of human hearing (approximately 20 kHz).

An important feature of ultrasound is the ease with which it can be generated and detected, as well as the possibility of forming a beam with a high energy flux density. Ultrasound is generated and recorded using piezoelectric transducers.

At present, ultrasound has a very wide range of applications, especially in diagnostics. In particular, in medicine (ultrasonography, USG) it is used by specialists to visualise internal organs. Ultrasound is also employed in automation (motion sensors, alarm devices), in technological processes, in nondestructive testing for material defects, and for cleaning, crushing and heating materials, etc. Ultrasonic techniques make it possible to determine with high precision the speed of sound propagation in the investigated material and thereby to identify the type of material. Since ultrasound is only weakly attenuated in water, it has also found application in hydroacoustics (sonar). Ultrasonic distance meters are now used increasingly often in everyday practice; therefore, a good knowledge of the fundamentals of this measurement technique is very important.

II. Topics for the preliminary colloquium

1. Construction and operation of an ultrasonic head and detector.
2. Methods of generating ultrasound: mechanical methods, the piezomagnetic and piezoelectric effects, magnetostriction and electrostriction.
3. Wave properties of ultrasound – the Doppler effect.
4. Ultrasonic acoustic waves: propagation speed, wave energy, intensity of the wave.
5. Acoustic waves in unbounded media and in media of finite dimensions.
6. Ultrasonic acoustic field: near field and far field.
7. Attenuation of ultrasonic waves, attenuation coefficient.
8. Use of ultrasound for distance measurements.
9. Other applications of ultrasound, ultrasound in nature.

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10. Principle of operation of a flaw detector with a digital transducer.

III. Apparatus

1. Instruments:

- Olympus EPOCH 1000i flaw detector,
- heads with piezoelectric transducers,
- calibration blocks (reference standards),steel blocks with defects (real defects or drilled artificial defects),
- cylinders made of various materials for measurements of the speed of sound,
- other materials such as plexiglass, marble, etc.

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2. Measurement station – set of samples for study

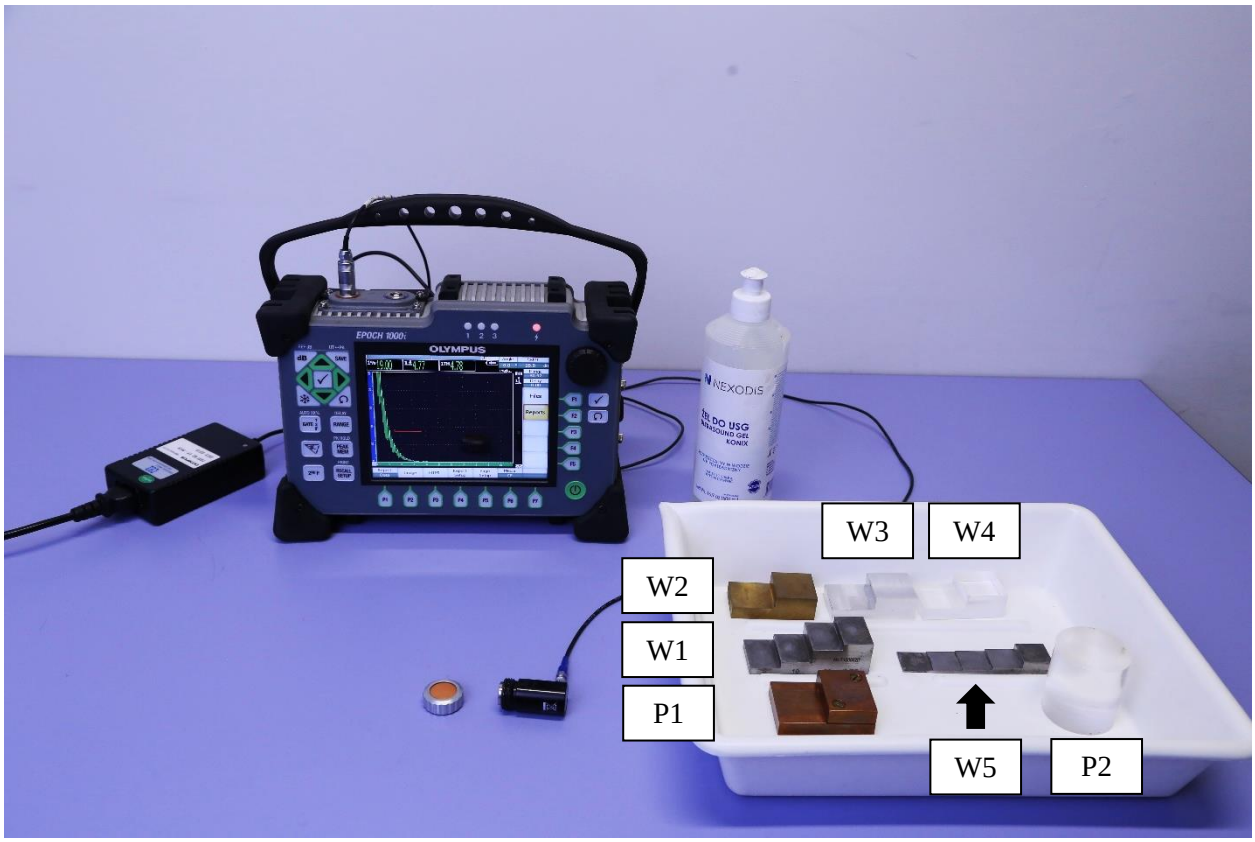

Photo 1. Measurement system, patterns, samples (examples).

W1 – steel reference block

W2 – brass reference block

W3 – aluminium reference block

W4 – plexiglass reference block

W5 – steel reference block

P1 – sample made of an unknown material

P2 – plexiglass sample

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Description of the functions of the flaw detector and preliminary settings

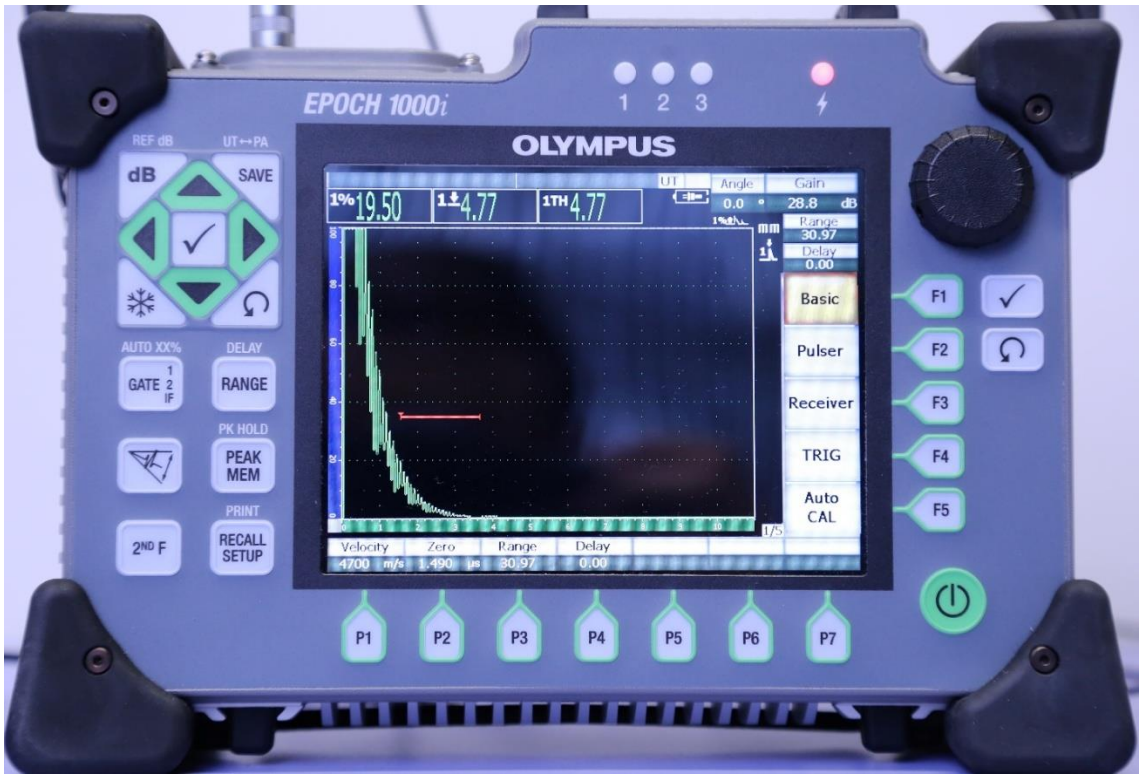

Photo 2. EPOCH 1000i flaw detector

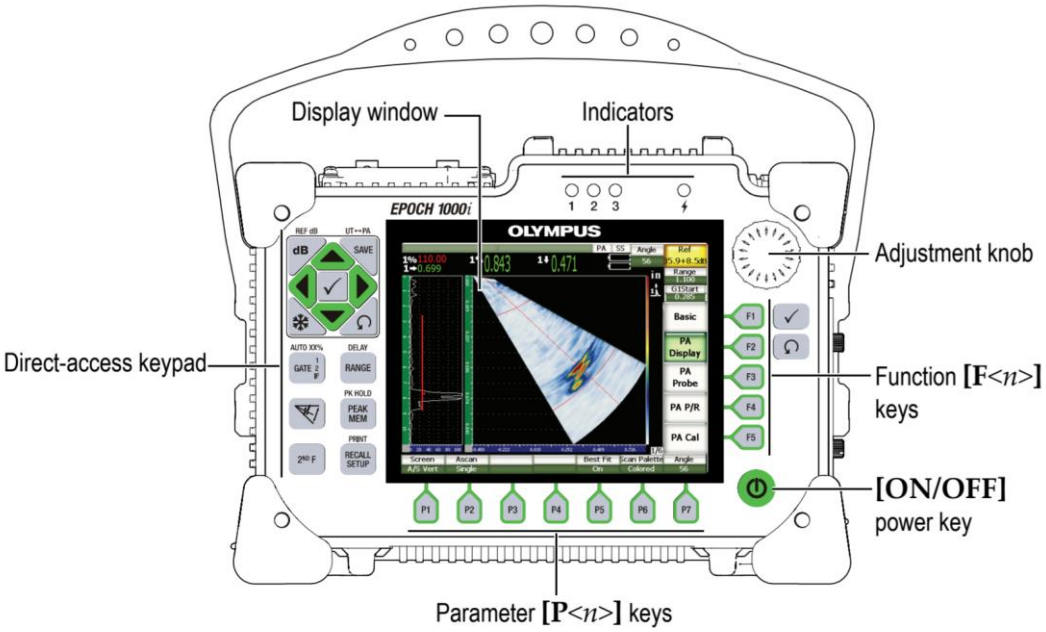

Fig. 1. Marking of buttons on the flaw detector.

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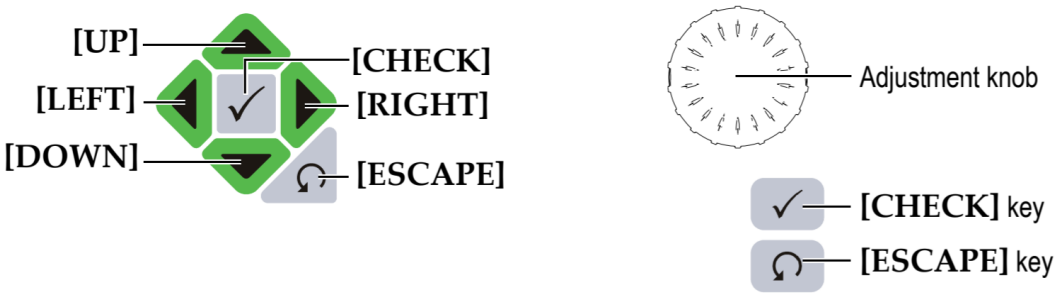

Fig 2. Marking of selected buttons.

Flaw detector presets

1. Switch on the flaw detector using the ***ON/OFF*** button.
2. Apply coupling gel to the reference block and then place the probe on its surface. The ***PF4R-10*** probe should be connected to the ***T/R*** socket. The probe must be pressed to the sample so that it adheres firmly to the material.
3. Using the ***Adjustment knob***, select page ***3/5*** and then press ***F2*** to select the ***Meas Setup*** menu. Using button ***P2*** and the knob, set the unit (***Unit***) to [***mm***]. Confirm by pressing ***ESCAPE*** to unlock the ***Velocity*** parameter. Then use ***ESCAPE*** again to return to the main menu, page ***1/5*** (***Basic***).
4. Press the ***dB*** button; the ***Gain*** window in the upper right corner will be highlighted. Using the knob, set the initial gain to approximately 20–25 dB.
5. In the main ***Basic*** view (page 1/5), press button ***P2*** to select the ***Zero*** parameter and use the knob to set its value to ***0.000 µs***. Confirm with ***ESCAPE***.
6. Similarly, set the ***Delay*** parameter to ***0.00 mm***.
7. Set the ***Range*** parameter (button ***P3***) and adjust it with the knob so that the sound path in the selected material is visible. At least four echoes should be visible.
8. On page ***1/5*** press ***F4*** to select the ***TRIG*** menu.
9. Set the following parameter values: ***Angle*** = ***0.0*** and ***Thick*** = ***0.0 mm***.
10. On page ***1/5*** press ***F3*** to select the Receiver menu. Set the ***Reject*** parameter to ***0%***.
11. If gate 1 (measurement gate 1 – a red horizontal line) is not displayed on the screen, go to page ***2/5*** and press ***F1*** to select the ***Gate 1*** function. Change ***Status*** to ***On***.
12. If measurement gate 2 (a light blue horizontal line) is displayed on the screen, go to page ***2/5*** and press ***F2*** to select the ***Gate 2*** function. Change ***Status*** to ***Off***. At the initial stage of the exercise this function will not be needed.

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IV. COURSE OF THE EXERCISE

PART I

Method I

Calibration for a reference block of known thickness (**W1**).

1. Place the probe on the 10 mm calibration block.
2. Using the knob, select page ***1/5*** and the ***Basic*** function. Press button ***P3*** (***Range***) and extend the time base so that the first four echoes are visible.
3. On page ***2/5*** press ***F1*** and select the ***Gate 1*** function. Press ***P2*** to select the ***Start*** parameter and use the knob to shift the measurement gate right/left so that the first echo is enclosed within the gate.
   NOTE:
   If the width of the gate is too large (covers more than one echo), use the knob to select page ***2/5***, then press ***P3*** to select the ***Width*** option and reduce the width of the gate using the knob. Confirm with the ***CHECK*** button. Then return to point 3 above.
4. On page ***1/5*** press ***F5*** to select the ***AutoCAL*** function. Press ***P1*** to select ***CAL Mode*** and choose the ***Thickness*** option.
5. Press the ***dB*** button and use the knob to adjust the height of the first echo so that its amplitude is approximately 80% of the vertical scale. Confirm with ***CHECK***.
6. On page ***1/5*** select ***AutoCAL***, press ***P3*** to choose ***CALZero*** and enter the thickness of the reference block (in this case 10.00 mm). Confirm with ***CHECK***.

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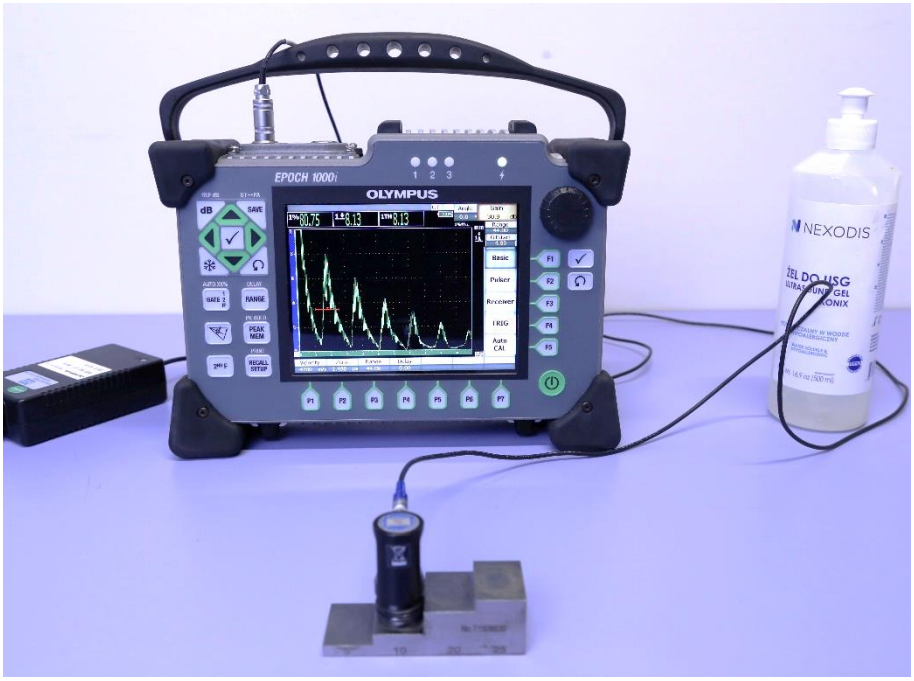

Photo 3. Sample measurement for a 10 mm thick standard.

7. Place the probe on the 25 mm calibration block and repeat steps 2–5.
8. On page ***1/5*** (Basic) press ***F5*** to select ***AutoCAL***, then press ***P2*** to choose ***CAL Velocity***. Enter the value 25 mm and select ***Calculate***, confirming with ***CHECK***.

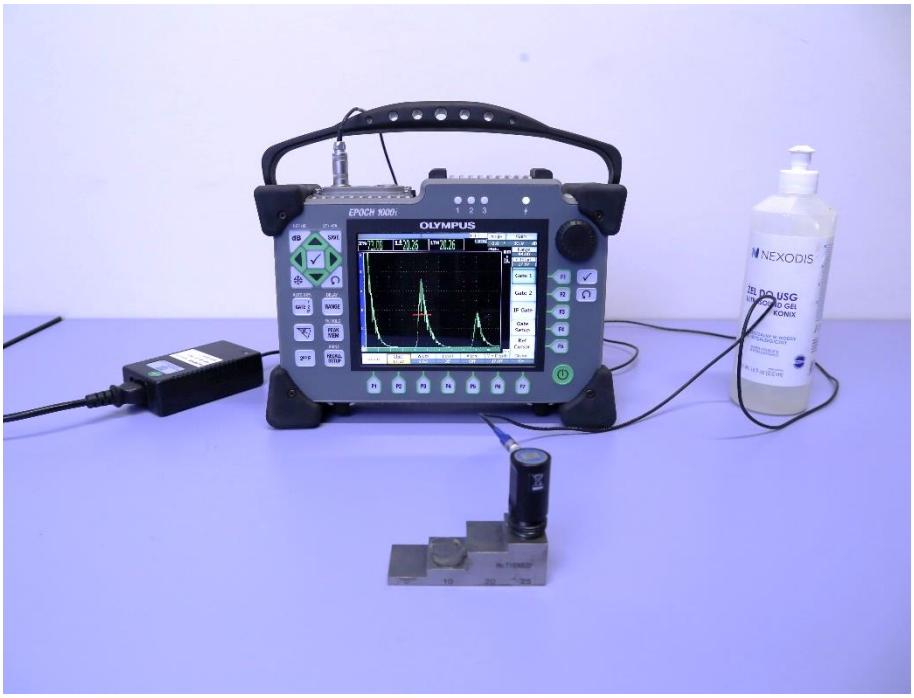

Photo 4. Sample measurement for a 25 mm thick standard.

9. On page ***1/5*** (***Basic***) read the value of the speed of sound for the steel of which the reference standard is made.

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NOTE!

If the calibration has been performed correctly, after placing the probe on the 10 mm reference block, its thickness should be displayed in the measurement field 1TH. Analogously, for the 25 mm reference block, its thickness should appear in field 1TH when the probe is placed on it.

1. Measurement of the thickness of selected samples using two methods:

1. Agree with the instructor which samples are to be investigated.
2. Place the head on the investigated sample. Ensure that at least four echoes are visible on the screen.
3. Set the measurement gate on the first echo and read the thickness of the material from the display.
4. The number of measurements and measurement points should be agreed with the instructor.
5. Perform independent measurements of the thickness of the investigated material using a calliper or a micrometer screw.

2. Determination of the speed of sound in selected:

1. Using the procedure ***Calibration for a reference block of known thickness*** and the reference blocks W2 (brass), W3 (aluminium) and W4 (plexiglass), determine the speed of sound in these materials. For this purpose, first measure the thickness of the reference blocks with a calliper or micrometer screw. The number of measurements should be agreed with the instructor.
2. After determining the speed of sound in plexiglass, use the flaw detector to determine the height of the plexiglass cylinder P2.

Method II

Determination of the speed of sound in a material of known (measured) thickness (At least two echoes reflected from the back wall of the sample are required.)

1. Perform the steps described in section ***Preliminary settings of the flaw detector***.
2. Switch on measurement gate 2 (light blue horizontal line): go to page ***2/5***, press ***F2*** to select ***Gate 2***, and set ***Status*** to ***On***.
3. Agree with the instructor which samples are to be investigated. (A sample analysis is presented below for specimen P1.)
4. Measure the thickness h of the sample using a calliper or micrometer screw.

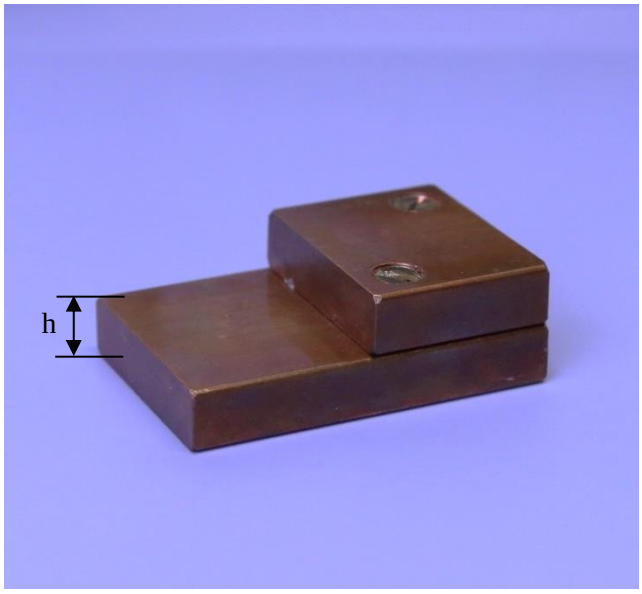

Photo 4. Sample made of unknown material.

5. Place the probe on the surface of the material so that it adheres firmly. During measurement, ensure that the probe does not lose contact with the sample.
6. Set measurement gate 1 on the first echo.
7. Set measurement gate 2 on the fourth echo.

   NOTE!

   Jeżeli na górnej części wyświetlacza nie widać wartości 1TH oraz 2TH przejdź na stronę ***3/5*** i wybierz przyciskiem ***F2*** funkcję Meas Setup, następnie P1 wybierz opcję ***Reading Setup*** i zmień parametr na ***Auto***. Po wyjściu przyciskiem ***ESCAPE*** powinny być widoczne wartości 1TH oraz 2TH. If the values 1TH and 2TH are not visible at the top of the display, go to page ***3/5*** and press ***F2*** to select the ***Meas Setup*** function. Then press ***P1*** to choose Reading Setup and change the parameter to Auto. After returning to the main display using ESCAPE, the values 1TH and 2TH should appear.

8. On page ***1/5***, after selecting ***Basic*** (***F1***) and then ***P1***, adjust the ***Velocity*** parameter so that the value displayed in field 2TH is four times the thickness of the plate. ***Example***: If the thickness of the plate is 10 mm and the value 1TH is, for example, 10.101 mm and 2TH is 40.109 mm, then adjust the value of the velocity so that 2TH becomes 40.101 mm. When compensating, check that the echo has not moved outside the measurement gates; if it has, correct the position of the gates accordingly.
9. On page ***1/5*** press ***P2*** to select the ***Zero*** parameter and set its value so that for measurement gate 1 the displayed thickness corresponds exactly to the measured thickness ***h*** of the sample.
10. If the calibration is successful, read the value of the speed of sound from the ***Velocity*** field.

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PART II

Determination of the location of defects

1. Perform the calibration as in Method I.
2. Using the horizontal scale, determine the depth of each defect analogously to the measurement of material thickness.
3. Record the measurement results (screen documentation, sketches, tables, etc.).
4. Repeat the measurements for several different defects in the investigated sample.
5. Measure the position of the defects directly (e.g. using a calliper, based on the known geometry of drilled holes).
6. Compare the results obtained by ultrasonic measurements with those obtained from direct measurements.
7. Repeat the investigation for the samples indicated by the instructor.

Determination of the geometry of the material indicated by the instructor

1. Determine the geometry of a steel block by scanning its entire volume with the ultrasonic probe. Sketch the shape of the block.
2. Using the experience gained in the above exercises, determine the dimensions of the block as accurately as possible.
3. Record the measurement results.
4. For comparison, repeat the measurements using a calliper (direct method).
5. Perform the investigations for the samples indicated by the instructor.

Badania przeprowadzić dla próbek wskazanych przez prowadzącego.

PART III - COMPLETION OF THE EXERCISE

After completing all measurements:

- Switch off the device using the ON/OFF button.
- Carefully wipe the probe with paper to remove the coupling gel/oil.
- **Clean the samples with paper and, if necessary, wash them under running water in order to remove any remaining gel/oil that could cause corrosion of the material.**

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V. REQUIREMENTS FOR REPORT PREPARATION

1. Przeprowadzić identyfikację badanych materiałów na podstawie porównania prędkości dźwięku uzyskanych eksperymentalnie z prędkościami tablicowymi. Discuss and compare the two methods of measuring the thickness of a homogeneous block (e.g. steel) – Method I and Method II. Document the most important results and perform an uncertainty analysis.
2. Describe the method of defect localisation and document the investigations performed. Compare the results obtained with the positions and sizes of drilled holes determined using a calliper.
3. Compare the results of the measurements of a steel block obtained by ultrasonic methods with those obtained by the direct method (using a calliper). Perform an error analysis.
4. Identify the investigated materials by comparing the experimentally determined sound velocities with tabulated values.
5. Formulate conclusions from the experiment.

VI. Literature

1. R. Resnick, D. Halliday, „Physics”, Vol. 1, PWN, Warszawa 1997
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3. P. Gołąbek, Korneta, B.Rojek „Laboratorium z podstaw badań ultradźwięków” Ultramet.
4. A. Oleś "Metody doświadczalne fizyki ciała stałego", WNT, Warszawa 1998
5. EPOCH 1000 Series User’s Manual, 2011