Ultrasound in laboratory course

Ultrasound is used in a wide variety of ways in today's society. The use of ultrasound has spread throughout all fields, from households to medicine to special industrial applications. Examples of this include, among others, humidifiers, ultrasonic cleaning devices, distance meters, the sonography of internal organs or foetuses, blood-flow analyses, therapeutic ultrasound, liquid level meters, ultrasonic welding, echo sounding and non-destructive testing.

Knowledge of the basics of the generation, propagation and interaction of ultrasound, the fundamental structure of ultrasonic devices and special measuring methods is thus useful or even necessary for all natural scientific, technical and medical subjects.

The following examples of practical training experiments are divided into three categories.

PHY: In the category of physics, the basics of the creation, propagation and interaction of ultrasound and the methodology of ultrasonic methods are dealt with.

IND: The category of industry includes experiment suggestions for some selected industrial applications of ultrasound and the subject of non-destructive testing.

MED: The category of medicine contains examples for experiments on medical subjects.

The experiment descriptions give an overview of the tasks and related topics of the individual experiments. There is a short theoretical introduction to the basics and/or the groups of themes being dealt with and the presentation of an exemplary experiment result. The material list contains all the necessary devices, accessories and consumable materials with order numbers.

In addition, supplementary and more advanced experiments are suggested. All presented experiments are examples which can be combined and/or extended as you wish. In this way, both short basic experiments and complex subject areas can be dealt with (by combination). As a simple aid to orientation, the experiment descriptions are provided with pictograms which describe:

I II III an easy, medium or higher degree of difficulty and/or

a short, medium or long experiment duration.

The experiments are constantly revised and expanded by us. We are of course happy to help you with further information, or you can visit our website at **www.gampt.de**.

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Experiments

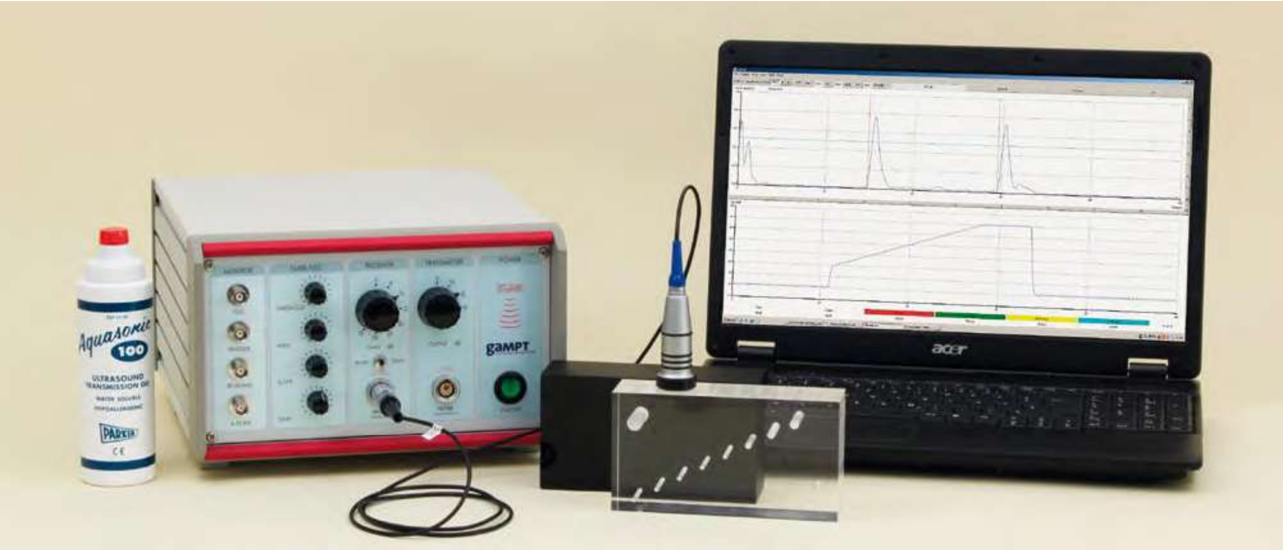
Physics 54-76

Industry 77-85

Medicine 86-93

PHY01 Basics of pulse echo method (A-Scan)

A sample with built-in discontinuities is examined by means of the pulse echo method. Amplitude scans are carried out from different sides of the sample. The echo signals imaged in the recorded A-Scan images are examined and analysed.



Related topics

Propagation of ultrasonic waves, time of flight of sound, sound velocity, characteristic acoustic impedance, reflection and transmission, pulse echo method, ultrasonic A-Scan

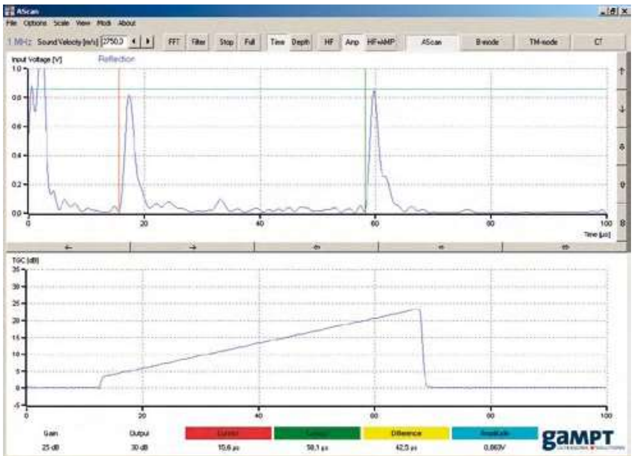
The pulse echo method forms the basis of many imaging methods in non-invasive medical diagnostics and non-destructive testing. In this method, electrical pulses are transformed into mechanical vibrations by an ultrasonic probe. These are coupled into the sample being examined and pass through it as sound waves. Waves that are reflected on discontinuities return to the probe and are converted back into an electrical signal. The chronological recording of the amplitude of this signal (amplitude scan) is graphically imaged as a so-called ultrasonic A-Scan image. Based on the reflection echoes in the A-scan image, times of flight can be determined, the sound velocity in the material calculated and discontinuities in the sample detected.

Equipment

Ultrasonic echoscope GS200	10400
Ultrasonic probe 1 MHz	10151
Test block (transparent)	10201
- optional: test block (black)	10204
Ultrasonic gel	70200

Results

The screen shot of the measurement software shows a typical ultrasonic A-Scan image of the test block. One can observe: the initial echo, the echo of a discontinuity and the bottom echo at the material-air boundary at the opposite end of the sample. The value to be determined for the sound velocity in the test block (acrylic) is around 2700 m/s. From the ascertained sound velocity and the measured times of flight of the reflection echoes of the discontinuities, their depth in the sample can be established.



Related experiments

PHY02 Sound velocity in solids
PHY03 Acoustic attenuation in solids
PHY21 Reflection and transmission at boundaries
IND01 Non-Destructive Testing (NDT)
IND06 Angle beam testing
MED02 Ultrasonic imaging at breast phantom (mammasonography)
MED04 Biometry at the eye phantom

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PHY02 Sound velocity in solids

In the experiment, the longitudinal sound velocity in acrylic is to be examined and determined at two different sound frequencies. For this purpose, time of flight measurements are carried out according to the pulse echo method (ultrasonic A-Scan) at three acrylic cylinders of different lengths.

Related topics

Propagation of ultrasonic waves, characteristic acoustic impedance, reflection, time of flight, sound velocity, pulse echo method, ultrasonic A-Scan

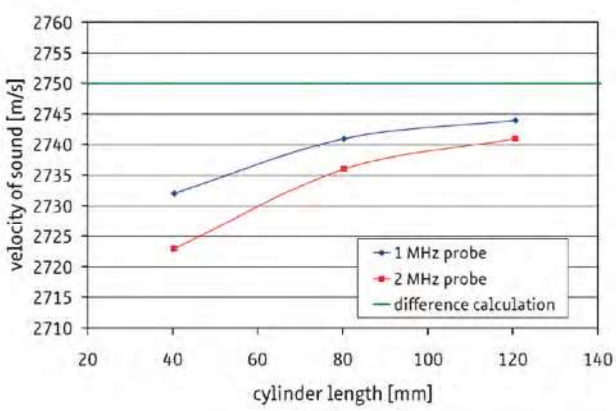
Ultrasonic waves propagate in a medium with a material-dependent velocity, which can be frequency-dependent. In gases and liquids sound propagation only takes place in the form of longitudinal waves. In solids, on the other hand, due to their elastic properties, shear waves can also occur. Shear and longitudinal waves generally propagate at different velocity. The sound velocity of the longitudinal waves generated in a solid with perpendicular sound coupling can be simply determined by means of time of flight measurements using the pulse echo method. By using samples of different lengths and sound probes with different frequencies, the intention in the experiment is to make statements on the frequency dependence of the sound propagation and on sources of errors caused by the structure of the ultrasonic probes that are used.

Equipment

Ultrasonic echoscope GS200	10400
Ultrasonic probe 1 MHz	10151
Ultrasonic probe 2 MHz	10152
Test cylinder set	10207
Ultrasonic gel	70200

Results

The sound velocities calculated from the times of flight measured show a systematic error, the influence of which becomes smaller as the measuring length is increased, and which is caused by the time of flight also measured in the protection/adaption layer of the probes. In this case, the 2 MHz probe possesses a thicker protection/adaption layer so that the sound velocities determined with it show a greater error. Using a difference calculation from two measurements with different sample lengths, this error can be eliminated (green line in the graphic, c_L = 2750 m/s, same values for both frequencies, no dispersion).

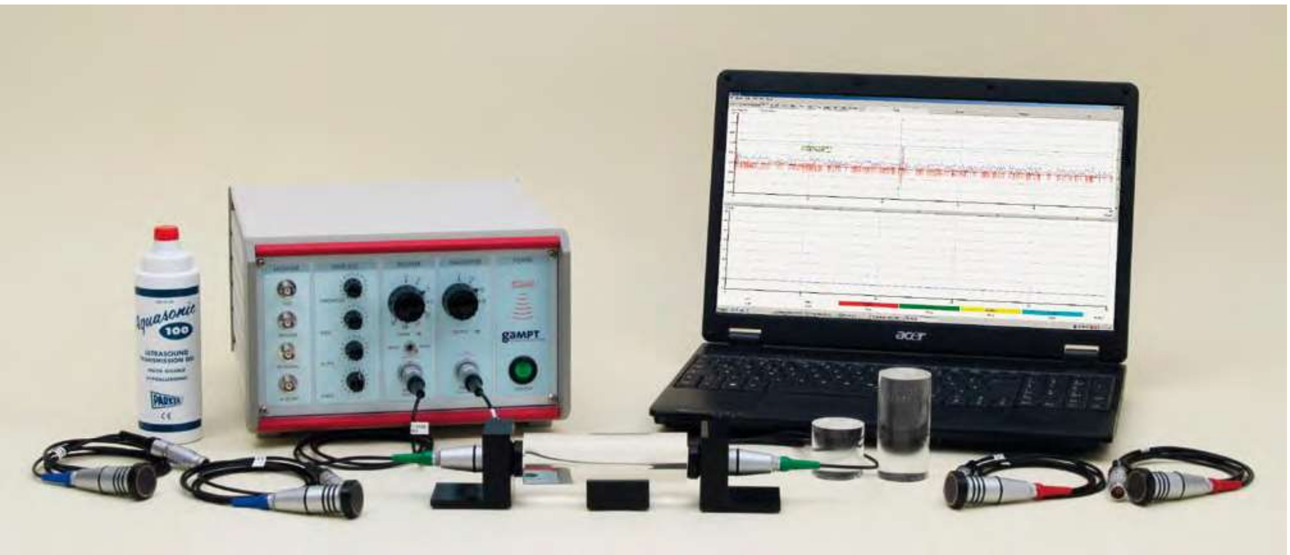


Related experiments

PHY07 Shear waves in solids
IND01 Non-Destructive Testing (NDT)
IND06 Angle beam testing
MED04 Biometry at the eye phantom

PHY03 Acoustic attenuation in solids

By means of amplitude measurements according to the ultrasonic transmission method in samples of different lengths, the attenuation of an ultrasonic wave on its way through a medium is determined. Ascertaining the acoustic attenuation coefficient at different ultrasonic frequencies sheds light upon the frequency dependence of acoustic attenuation.



Related topics

Acoustic attenuation in solids, scattering, absorption, reflection, attenuation coefficient, frequency dependence of acoustic attenuation, transmission measurement

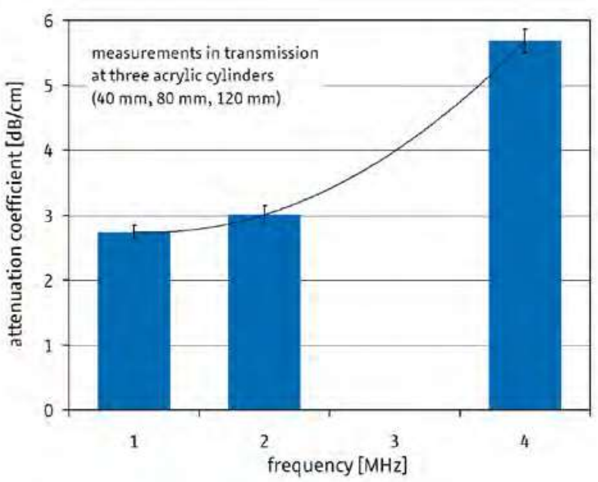
Sound waves lose energy on their way through a medium due to different processes such as absorption, scattering or reflection. This loss of energy causes a change in the sound intensity, which decreases as the distance increases. The strength of this attenuation is dependent on the material. It can be determined by the measurement of the amplitudes of transmission pulses or reflection pulses in an amplitude scan for different path lengths and can be described by the material-specific attenuation coefficient. In the experiment, these measurements are carried out at acrylic cylinders of different lengths. In order to be able to make statements about the frequency dependence of sound attenuation in acrylic, these measurements are carried out for different sound frequencies.

Equipment

Ultrasonic echoscope GS200	10400
2 ultrasonic probes 1 MHz	10151
2 ultrasonic probes 2 MHz	10152
2 ultrasonic probes 4 MHz	10154
Test cylinder set	10207
Ultrasonic gel	70200

Results

The graphic presents the measurement values of an example measurement in through-transmission at 3 acrylic test cylinders of different lengths. In the examined frequency range from 1 MHz to 4 MHz the attenuation coefficients ascertained lay between 2.7 dB/cm and 5.7 dB/cm. It can be seen that the acoustic attenuation in acrylic sharply increases as the frequency rises. In order to extend the database with other path lengths the cylinders can also be investigated with the reflection method.



Related experiments

PHY04 Acoustic attenuation in liquids
IND01 Non-Destructive Testing (NDT)
IND03 Level measurement
MED02 Ultrasonic imaging at breast phantom (mammasonography)

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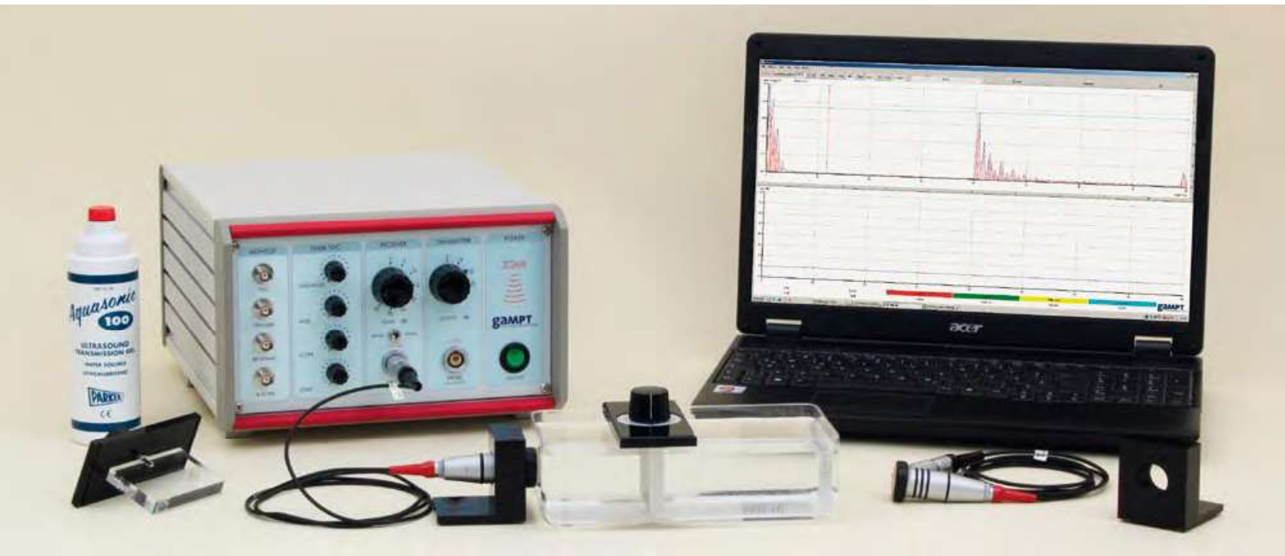
PHY04 Acoustic attenuation in liquids

In the experiment, the attenuation of sound waves in different liquids in dependence on the sound path is investigated. For each of the liquids the acoustic attenuation coefficient is determined by linear regression.



Related topics

Sound propagation in liquids, longitudinal waves, reflection, absorption, scattering, acoustic attenuation in liquids, attenuation coefficient

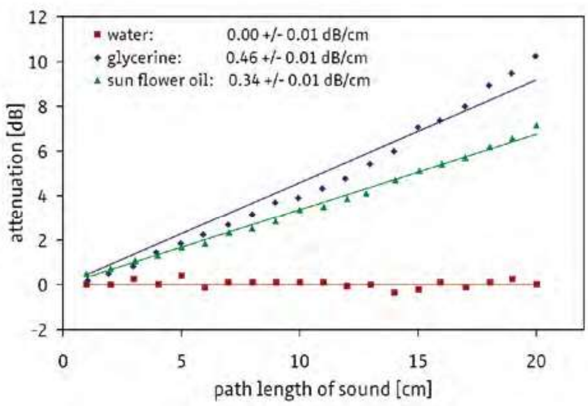
In gases and liquids sound propagation takes place in the form of longitudinal waves. Here, the sound waves can lose energy on their way through the liquid through absorption, reflection or scattering. In addition to these, sound field geometry can also influence acoustic attenuation. In the experiment, the amplitudes of the reflection echoes from a simply movable sound reflector made of aluminium are measured. Due to its shift in the liquid to be investigated, the amplitude values for a large number of different sound paths can be quickly ascertained using the pulse echo method. The attenuation of the signal amplitude A can here be described by the general law of attenuation $A = A_0 \cdot e^{-\alpha x}$. For two different sound paths x_1 and x_2 the following linearised form results: $2 \cdot \mathrm{Ln}(A_2/A_1) = \alpha \cdot (x_1 - x_2)$. The attenuation coefficient α of the respective liquid can thus be determined by a linear regression via the measurement points in the attenuation sound path diagram.

Equipment

Ultrasonic echoscope GS200	10400
2 ultrasonic probes 2 MHz	10152
Shear wave set	10218
Ultrasonic gel	70200

Results

In the experiment acoustic attenuation is investigated in the examples of water, a commercially available sunflower oil and glycerine (86.5 %). The diagram shows the measurement values with the regression lines for determining the acoustic attenuation coefficients α. At the used frequency of 2 MHz, the measurement with water shows no measurable attenuation, so the influence of sound field geometry can be regarded as negligible for the measurements in the experiment.

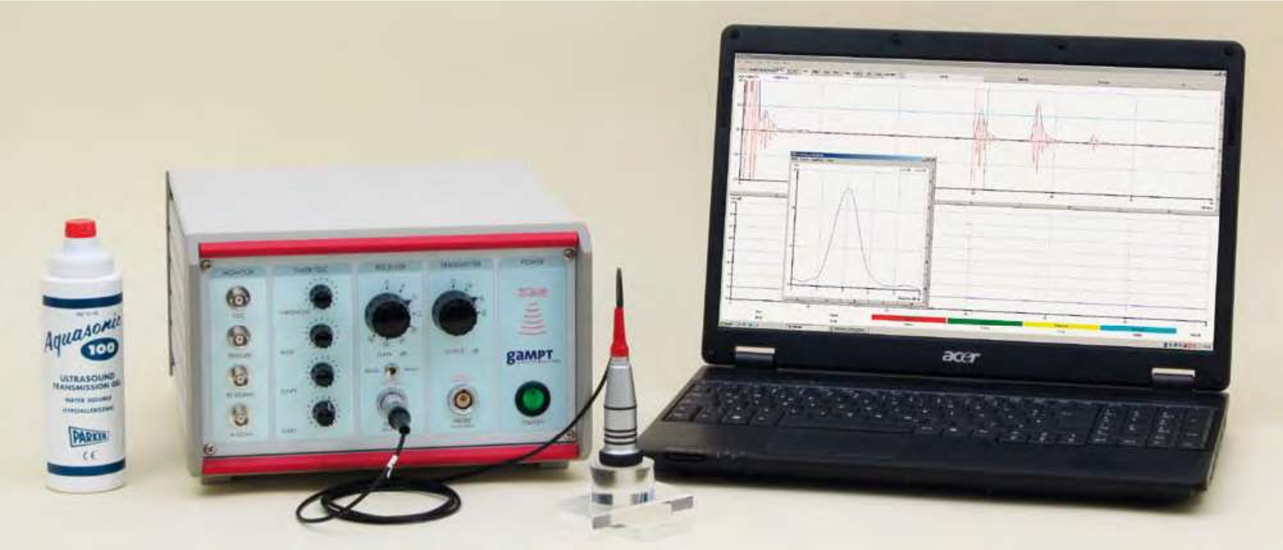


Related experiments

PHY01 Basics of pulse echo method (A-Scan)
PHY02 Sound velocity in solids
PHY03 Acoustic attenuation in solids
PHY19 Phase and group velocity

PHY05 Spectral investigations

Using the simple model of multiple reflection at a plate, the experiment shows the difference between the spectrum of a pulse and the spectra of periodic signals. The cepstrum is derived from the periodic spectrum and in both cases the periodic time is determined in order to calculate the plate thickness.



Related topics

Reflection, transmission, multiple reflection at one or several plates, single pulse, periodic signals, Fourier transformation, frequency spectrum, cepstrum

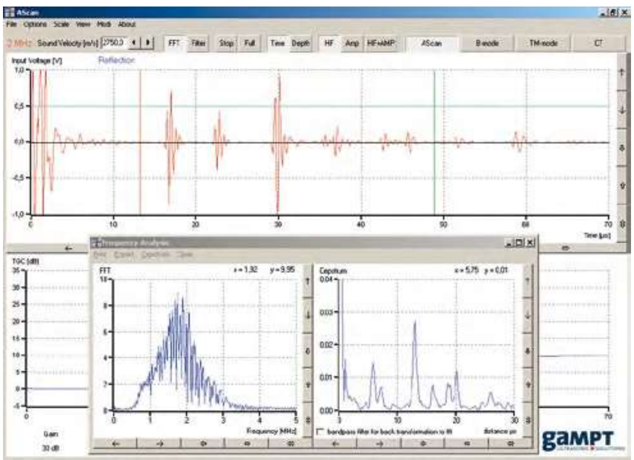
A time-variable signal such as the signal of an amplitude scan (A-Scan) can be broken down into its frequency components by means of a Fourier transformation (FFT - Fast Fourier Transformation). With this spectrum, small periodic structures can be made visible and characteristics such as layer thicknesses and scattering intervals can be derived. Whereas the Fourier transformation of a pulse only provides that pulse's basic maximum, the frequency spectrum of a periodic excitation (e.g. via the echo signals of a multiple reflection) shows maximums with equidistant intervals, from which the periodic time of the excitation (time of flight between the reflexes) results. By smoothing the frequency spectrum using the cepstrum method, the equidistant frequency interval can be isolated as a maximum on the time axis of the cepstrum.

Equipment

Ultrasonic echoscope GS200	10400
Ultrasonic probe 2 MHz	10152
Set of reflecting plates	10202
Ultrasonic gel	70200

Results

The screen shot of the measurement software shows the A-scan image of overlapping multiple reflections at two acrylic plates approx. 7.5 mm and 10 mm thick. Whereas the first echoes at the boundaries delay line/plate 1, plate 1/plate 2 and plate 2/air are still clearly recognisable, clear separation of individual echoes is no longer possible in the further progression of the amplitude signal. This state is reflected in the FFT spectrum via the signal. In the cepstrum, on the other hand, two times of flight (first maxima) can be determined: 5.75 µs and 7.2 µs. With a sound velocity of around 2700 m/s, this yields plate thicknesses of 7.8 mm and 9.8 mm.



Related experiments

PHY02 Sound velocity in solids
PHY03 Acoustic attenuation in solids
PHY06 Frequency dependence of resolution power

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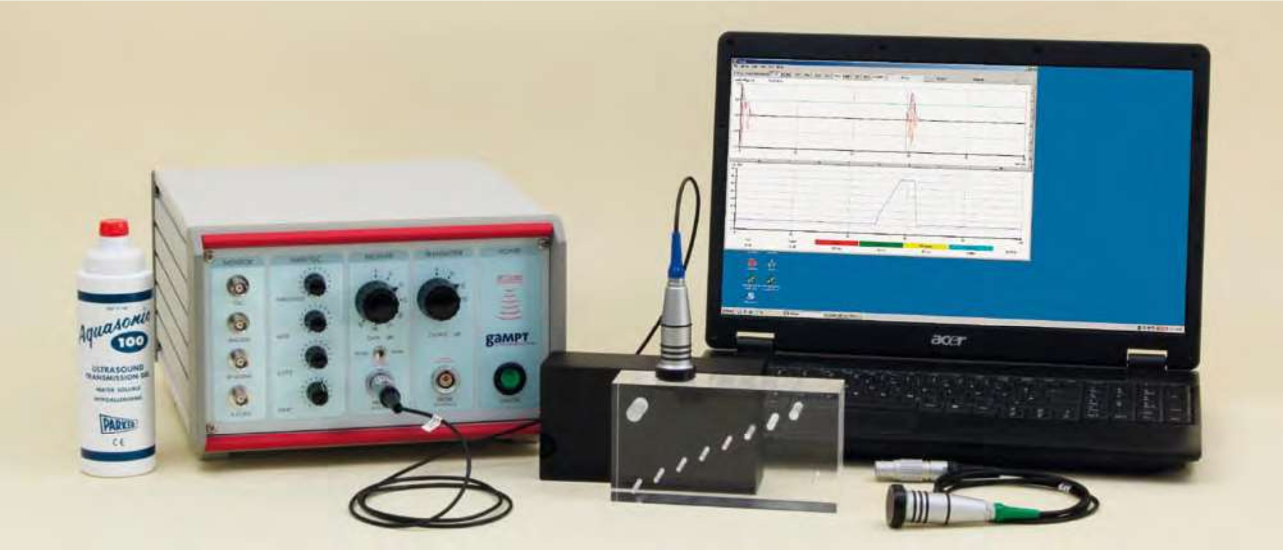
PHY06 Frequency dependence of resolution power

Based on two small and closely spaced discontinuities, the axial resolution power of two ultrasonic probes of different frequency is investigated. By analysing the recorded A-scan images, the connections between wavelength, frequency, pulse length and resolution power are demonstrated.



Related topics

Pulse echo method, amplitude scan, A-Scan presentation, sound frequency, periodic time, wavelength, sound velocity, pulse length, axial and lateral resolution

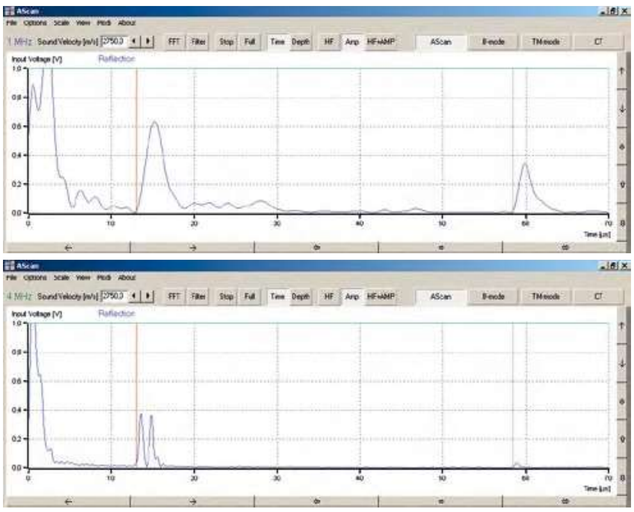
Investigation methods with ultrasonic systems are based on the exact assigning of the information on a point in the test area to a recorded ultrasonic echo. Because of this, the resolution power of the ultrasonic probes is enormously important. The resolution power can be described as the smallest possible distance between two points the echoes of which can still be separately detected. In the experiment, two neighbouring discontinuities in a test block are to be investigated with a 1 MHz probe and with a 4 MHz probe. The discontinuities are chosen, with regard to size, location and spacing, so that differentiation is only possible with one of the two test probes. In this way, the influence of frequency on the axial resolution power of an ultrasonic probe can be clearly shown.

Equipment

Ultrasonic echoscope GS200	10400
Ultrasonic probe 1 MHz	10151
Ultrasonic probe 4 MHz	10154
Test block (transparent)	10201
- optional: test block (black)	10204
Ultrasonic gel	70200

Results

In the experiment, first of all, a slightly attenuated echo is searched for with each of the two ultrasonic probes and the frequency, wavelength and pulse length determined. After this, the double discontinuity of the test block is investigated. The screen shots of the measurement software show recorded A-Scan images of the double discontinuity (top 1 MHz, bottom 4 MHz). As well as the higher resolution power of the 4 MHz probe, however, the stronger attenuation of the 4 MHz signal is also made clear. In comparison to the 1 MHz probe, the bottom echo with the 4 MHz probe is almost no longer visible.

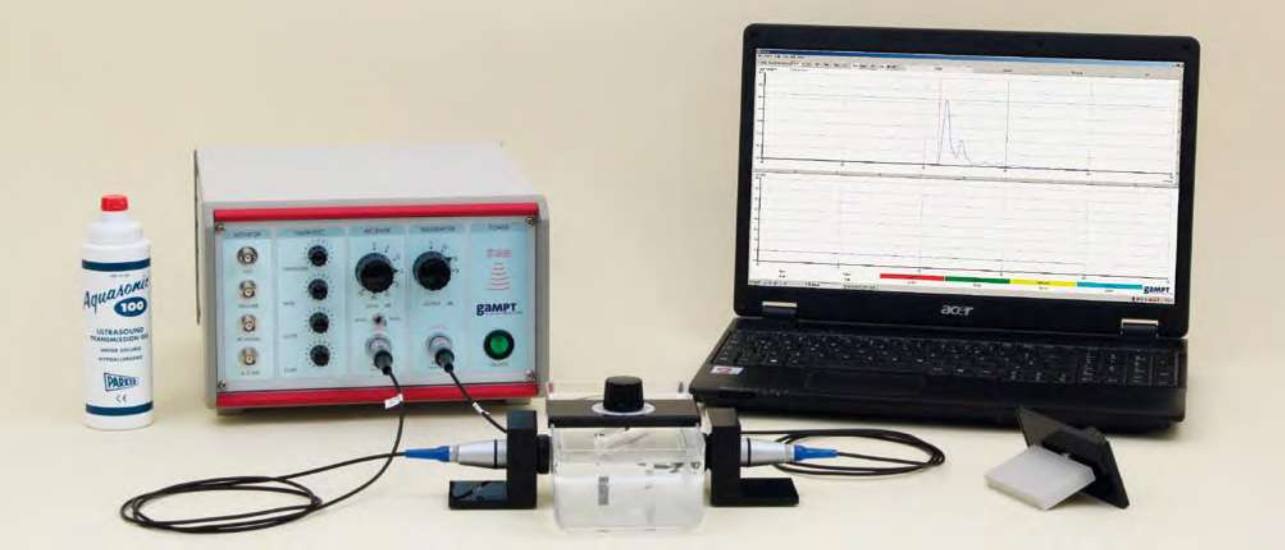


Related experiments

PHY08 Ultrasonic B-Scan
IND01 Non-Destructive Testing (NDT)
MED02 Ultrasonic imaging at breast phantom (mammasonography)

PHY07 Shear waves in solids

Based upon the ultrasonic transmission through a plane parallel plate at different angles of incidence, the formation and propagation of longitudinal and shear acoustic waves in solids is investigated. From the determined longitudinal and transversal sound velocities, the elastic material factors such as the modulus of elasticity and shear and Poisson's ratio are derived for the plate materials used.



Related topics

Ultrasonic propagation in solids, transmission, reflection, longitudinal and shear waves and sound velocities, modulus of elasticity, modulus of shear, Poisson's ratio

Unlike in gases and liquids, in solids both shear and longitudinal waves can be excited due to their elastic material properties. During passage through a plane parallel plate longitudinal and/or shear waves are excited depending on the incidence angle. The angles of total reflection for the longitudinal and shear wave and the angle at which the shear wave shows its maximum here correspond with the respective sound velocity. By recording the amplitudes of the longitudinal and transversal transmission signals over a corresponding range of the angle of incidence, these angles can be ascertained and the respective sound velocities determined. From the sound velocities, the elastic material factors of the plate materials used can be calculated, such as the modulus of elasticity and shear and the Poisson's ratio.

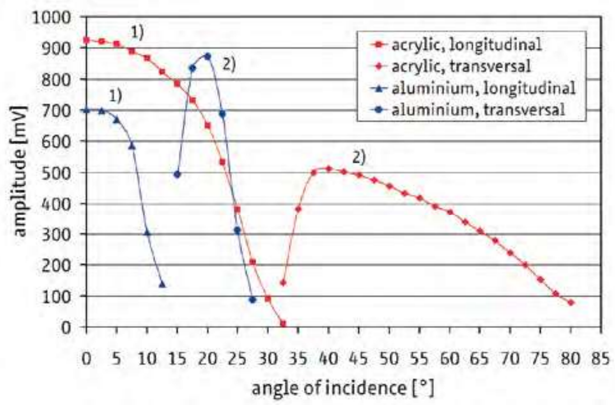
Equipment

Ultrasonic echoscope GS200	10400
2 ultrasonic probes 1 MHz	10151
Shear wave set	10218
Ultrasonic gel	70200

Results

The graphic shows the amplitude-angle curves for the determining of the angles for total reflection (longitudinal and transversal) and the maximum amplitude (transversal).

Independent of the material, but for different angles, the amplitude-angle dependence of the transmission can always be described by three categories: longitudinal signal only (1), a mixed mode of longitudinal and transversal signal and transversal signal only (2).



Related experiments

PHY20 Determination of focus zone
IND06 Angle beam testing
IND08 Detection of discontinuities
MED02 Ultrasonic imaging at breast phantom (mammasonography)

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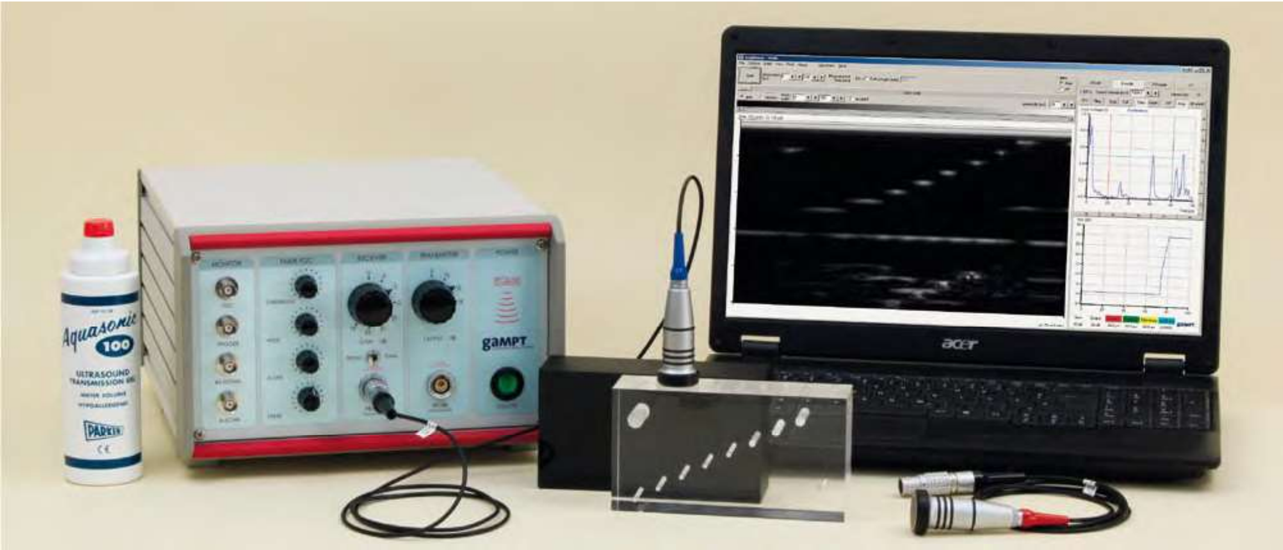
PHY08 Ultrasonic B-Scan

By recording the ultrasonic cross-sectional image of a simple test object "by hand" using an ultrasonic echoscope, the basics of the B-Scan method are clearly demonstrated. Special features regarding scan quality such as sound focus, spatial resolution or imaging errors are investigated and analysed.



Related topics

Sound velocity, reflection, transmission, reflection coefficient, ultrasonic echography, A-Scan image, grey scale representation, B-Scan image, lateral resolution, focus zone, image artefacts

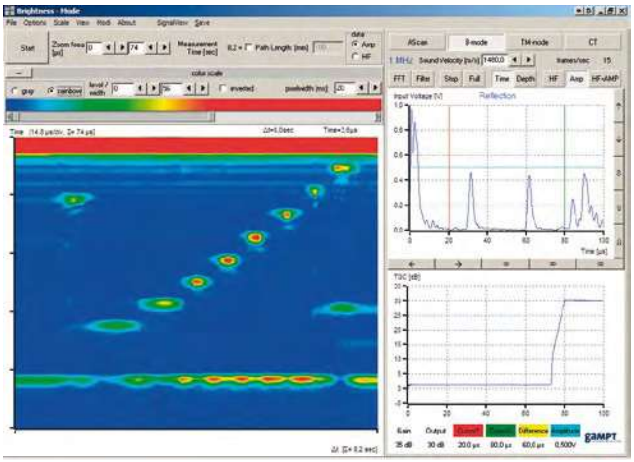
The conversion of the amplitude values of an amplitude scan into grey scale or colour values and the presentation of the time of flight as penetration depth yield a line of points with different brightness and/or colour values. The stringing together of such adjoining depth scans of an ultrasonic probe, which is guided along a line over the test area produces a sectional image, the so-called B-Scan image. Localisation along this line is based on the position of the probe and its movement speed. A simple way to obtain a B-Scan image is to guide the ultrasonic probe slowly by hand (compound scan). Scan quality is here dependent upon the coordinate-accurate transferral of scan points, the axial and lateral resolution of the ultrasonic probe, the grey scale and/or colour value resolution, the number of lines and imaging errors. In order to achieve e.g. exact lateral resolution, an additional coordinate-recording system is necessary such as a linear scanner.

Equipment

Ultrasonic echoscope GS200	10400
Ultrasonic probe 1 MHz	10151
Ultrasonic probe 2 MHz	10152
Test block (transparent)	10201
- optional: test block (black)	10204
Ultrasonic gel	70200

Results

The screen shot of the measurement software shows the B-Scan presentation of the investigation of a sample with defined, built-in defects. The manual scanning of the block makes the functioning of the B-Scan method "easy to grasp". The problems of movement artefacts with regard to lateral resolution caused "by hand" can be reduced by a mechanical scanning (PHY 16).



Related experiments

PHY16 Mechanical scan methods
PHY20 Determination of focus zone
MED02 Ultrasonic imaging at breast phantom (mammasonography)

PHY09 Ultrasonic computer tomography (CT)

In this experiment the formation of an ultrasonic CT scan image is clearly shown. The relevance and differences of individual measurement parameters such as attenuation and sound velocity are analysed and the influence of filters and image processing is investigated.

Related topics

Reflection, scattering, transmission, absorption, acoustic attenuation, sound velocity, resolution, ultrasonic echography (A-Scan, B-Scan), tomography, CT scan image, image processing, filters

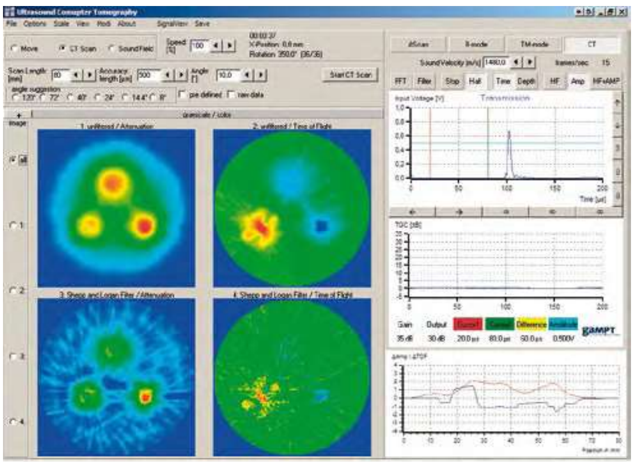
X-ray CT, MRT and PET are computer-aided imaging methods used in medical diagnostics, industry and research. Processes such as radiation absorption, nuclear magnetic resonance or particle emission are used to produce cross-sectional images by means of appropriately measurable physical quantities. Ultrasonic computer tomography is another CT method. It differs from X-ray CT in that instead of the attenuation of X-rays, the attenuation and times of flight of ultrasonic signals in the test object are measured. With our ultrasonic CT, line scans are recorded at different angles and put together to form a cross-sectional image. In this process, the sample arranged between transmission and receiving probe is moved and turned under computer control. The overlaying of the projections of individual scans can be followed step by step on the PC.

Equipment

Ultrasonic echoscope GS200	10400
CT scanner	60200
CT control unit UCT200	60210
2 ultrasonic probes 2 MHz	10152
CT sample	60121
CT reservoir	60120
Ultrasonic gel	70200

Results

In the experiment, CT scans for different settings of the transmission power and gain are recorded and comparatively analysed. The attenuation and time of flight tomograms are shown on the left in the measuring and controlling software, unfiltered at the top and mathematically filtered (contours reinforced) at the bottom. A simple form of image processing can be carried out by changing the brightness, contrast and colour.



Related experiments

PHY02 Sound velocity in solids
PHY03 Acoustic attenuation in solids
PHY04 Acoustic attenuation in liquids
PHY10 Characteristics of sound field

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PHY10 Characteristics of sound field

In this experiment the sound field of an ultrasonic probe in water is investigated by determining the sound pressure distribution in the axial and lateral direction by means of a hydrophone and characteristic sound field quantities are discussed.

Related topics

Sound field, near field, far field, focus zone, sound pressure, sound pressure distribution, sound velocity, sound intensity

The area in a medium in which sound waves are propagating is called the sound field. It possesses a certain geometry dependent on the material and the sound generation and/or sound coupling, decisively limits the lateral resolution power of an ultrasonic probe and can influence sound attenuation. The sound field can be described by sound field quantities such as sound pressure and sound particle velocity or sound energy quantities such as sound energy and sound intensity. By means of a hydrophone, the sound field in a liquid can be investigated by determining the sound pressure amplitude along and perpendicular to the sound field axis. Characteristic features such as near field length and sound field width can be derived from the amplitude distribution.

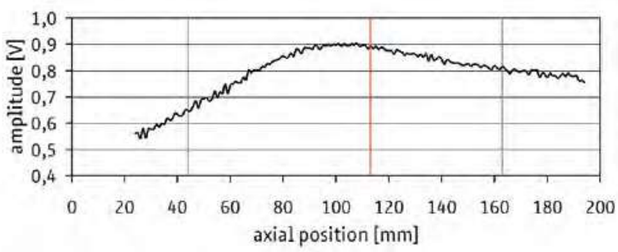
Equipment

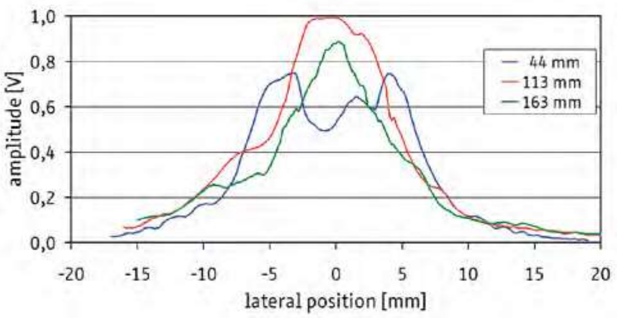
Ultrasonic echoscope GS200	10400
CT scanner	60200
CT control unit UCT200	60210
CT reservoir	60120
Ultrasonic probe 2 MHz	10152
Hydrophone	10450
Hydrophone support	60123
Ultrasonic gel	70200

Results

A theoretical near field length of 85 mm results for a 2 MHz probe (16 mm diameter) in water (c = 1497 m/s, T = 25 °C).

The hydrophone measurement along the sound field axis (top diagram) shows a maximum set back slightly at approx. 100 mm. The measurements of the lateral sound field distribution in different probe intervals (bottom diagram) show a local modulation of the signal amplitude in the area of the near field.



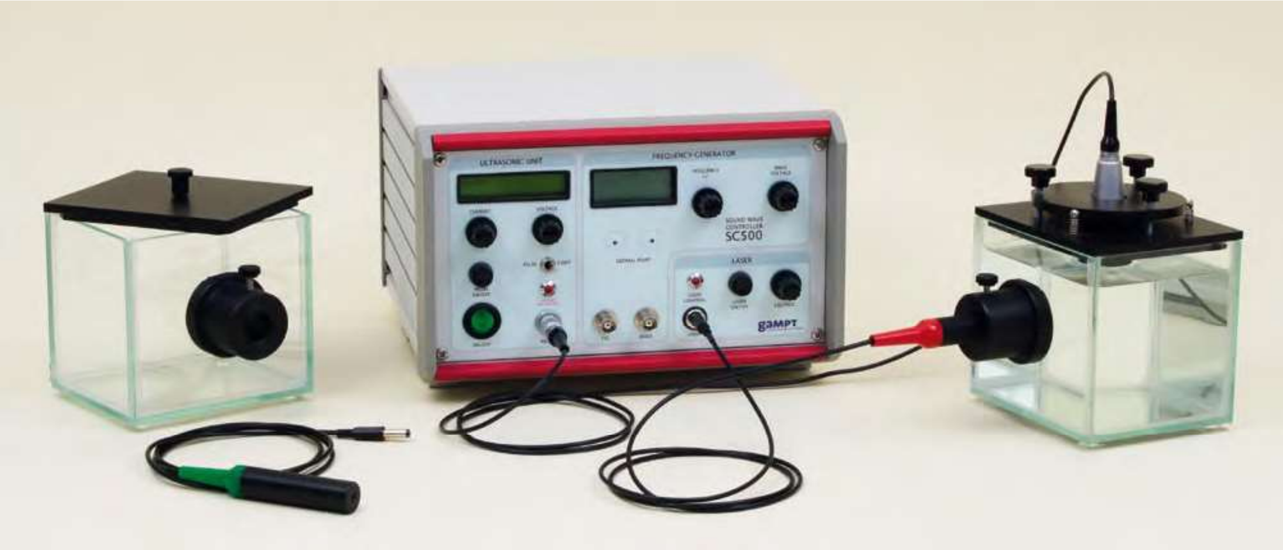


Related experiments

PHY04 Acoustic attenuation in liquids
PHY06 Frequency dependence of resolution power
PHY09 Ultrasonic computer tomography (CT)

PHY11 Debye-Sears effect

The experiment shows the diffraction of light at a standing ultrasonic wave (Debye-Sears effect) in a liquid. The sound velocity in the liquid (water) is determined using the dependence of the diffraction maxima on the wavelength of the diffracted laser light and the frequency of the ultrasonic wave.



Related topics

Debye-Sears effect, diffraction of light, diffraction grating, diffraction maxima, wavelength, sound velocity, standing and travelling wave

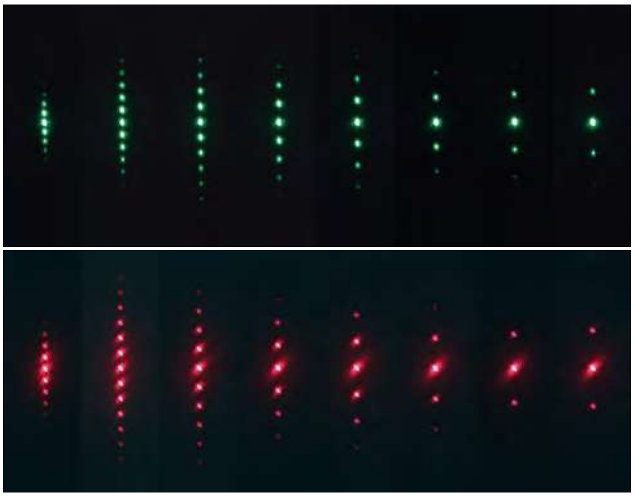
In 1932, Debye and Sears showed that light experiences a diffraction when passing through a liquid excited to high-frequency vibrations. Ultrasound can be made more or less “visible” using this effect. The density maxima and minima produced in the liquid by a standing or travelling ultrasonic wave here function like an optical diffraction grating. The grating constant of such a grating produced by an ultrasonic wave corresponds to the wavelength of this ultrasonic wave. It can be determined by means of the diffraction patterns of the light of a laser beam of a known wavelength. Because the wavelength is defined by frequency and sound velocity, the Debye-Sears effect can be used in this experiment structure in order to determine the sound velocity in the liquid being scanned with sound (e.g. water) with high accuracy.

Equipment

cw generator SC600	20100
Debye-Sears set	20200
Laser module (green)	20211
- optional: laser module (blue)	20212
AOM sample reservoir	20225
Cover for AOM sample reservoir	20223

Results

The graphic shows typical diffraction patterns for green and red laser light at a standing ultrasonic wave in water at sound frequencies from 3 MHz to 10 MHz (increment: 1 MHz). As the ultrasonic frequency is raised, the distances between the individual diffraction maxima also increase, although the longer-wave red laser light is more strongly diffracted. The number of orders of diffraction is largely determined by the transmission characteristics of the sound probe and the frequency-dependent attenuation.



Related experiments

PHY12 Projection of standing waves
PHY17 Acousto-optical modulation at standing waves
IND04 Concentration measurement with resonance cell

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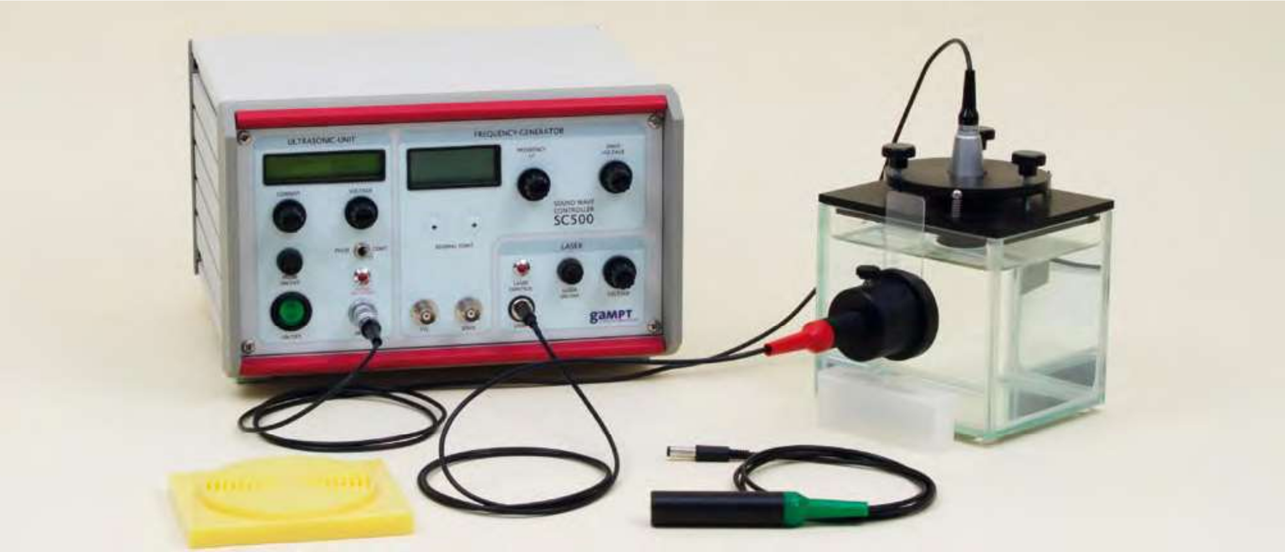
PHY12 Projection of standing waves

In the experiment a standing ultrasonic wave in a liquid is imaged by means of divergent laser light. The dependence of the brightness modulation of the projection images produced upon the wavelength of the light and the frequency of the ultrasonic wave is investigated and the sound velocity in the liquid (water) is determined.



Related topics

Sound wavelength, sound velocity, standing and travelling wave, divergent monochromatic light, refraction indices, focal length of an optical lens

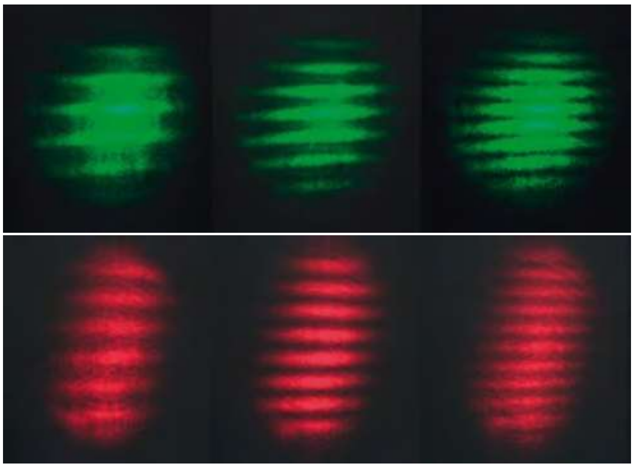
A standing ultrasonic wave in a liquid can be imaged by means of divergent monochromatic light. Due to the standing wave, sound pressure differences are produced in the liquid which are periodically repeated along the sound axis. The localised differences in density caused in this way result in locally differing and periodically repeating refraction indices along the sound axis. When monochromatic light is used, the projection of the standing wave therefore shows a light-dark modulation with periodically repeating brightness maxima which correspond to the density differences. The spacing of these brightness maxima can be used to determine the sound wavelength and thus the sound velocity in the liquid.

Equipment

cw generator SC600	20100
Debye-Sears set	20200
Laser module (green)	20211
- optional: laser module (blue)	20212
Projection lens	20230
Acoustic absorber	20227

Results

The projection images of standing ultrasonic waves in water (here at 2.8 MHz, 3.5 MHz and 4.5 MHz) obtained with green and red laser light show the reduction of the spacing of the brightness maxima to be expected with increasing sound frequency. The difference between green and red laser is here caused by the wavelength dependence of the refraction indices.



Related experiments

PHY11 Debye-Sears effect
PHY17 Acousto-optical modulation at standing waves

PHY13 Ultrasonic Doppler effect

The experiment provides an introduction to the basics of flow measurement on the basis of the acoustic or ultrasonic Doppler effect and examines its dependence on flow velocity and Doppler angle.

Related topics

Frequency shift, scattering, Doppler effect, Doppler angle, Doppler sonography, flow measurement

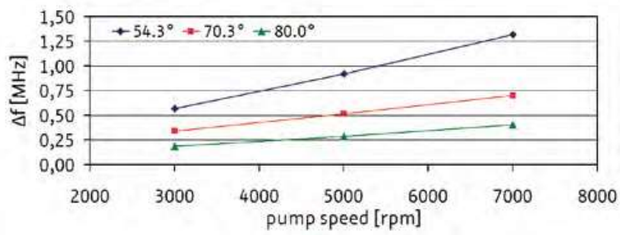
The term "Doppler effect" refers to the change in the perceived frequency of waves while the transmitter and receiver are in motion in relation to each other. This effect is used to image moving structures. For example, ultrasound can be used to determine the flow velocity and/or the flow rate of a flow of liquid. Here the frequency shift of an ultrasonic wave, which is coupled into the flow of liquid at a particular Doppler angle, is measured with scattering of the wave on small particles, such as impurities. In the experiment, the dependence of the Doppler frequency shift Δf on the flow velocity v (movement speed of the scattered particles) and the Doppler angle α is investigated for different fundamental frequencies f_0 by a variation of the pump power, the transmission frequency and the incidence angle. For a pulse-echo system with one ultrasonic probe the following relationship applies, presented in simplified form: $\Delta f \sim f_0 \, v \cos(\alpha)$.

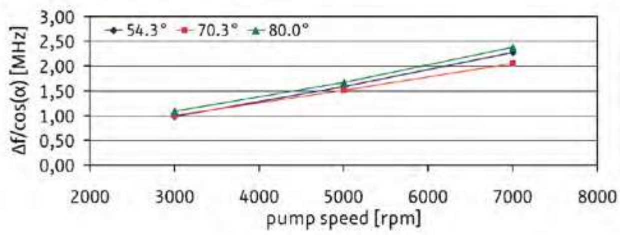
Equipment

Ultrasonic pulse Doppler FlowDop	50100
Ultrasonic probe 1 MHz	10131
Ultrasonic probe 2 MHz	10132
Ultrasonic probe 4 MHz	10134
Flow measuring set	50201
Centrifugal pump MultiFlow	50130
Doppler fluid	50140
Ultrasonic gel	70200

Results

The graphics show the frequency shift and the ratio $\Delta f/\cos(\alpha)$ in dependence on the pump power for different Doppler angles at the transmission frequency 2 MHz. The Doppler frequency shift determined increases as the rotational speed rises and as the Doppler angle becomes smaller. The quotient $\Delta f/\cos(\alpha)$ (the flow velocity v) is constant for even pump powers, i.e. no angle-dependent faulty measurement occurs.





Related experiments

PHY15 Fluid mechanics
IND05 Doppler flow measurement
MED03 Basics of Doppler sonography
MED05 Vascular ultrasound (angiology)
MED06 Peripheral Doppler blood pressure measurement

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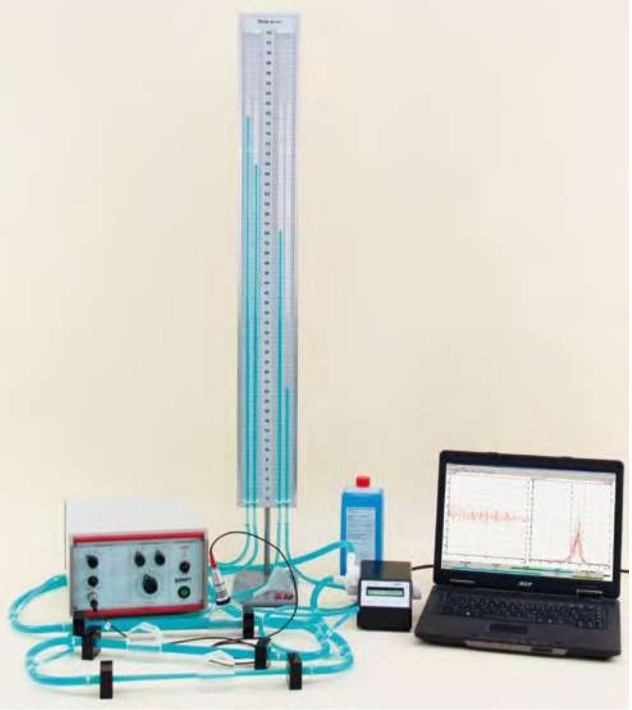
PHY15 Fluid mechanics

Flow measurements according to the ultrasonic Doppler method are used to demonstrate fundamental laws governing the flow of liquids in pipes and their dependence on the flow velocity and the pipe geometry.

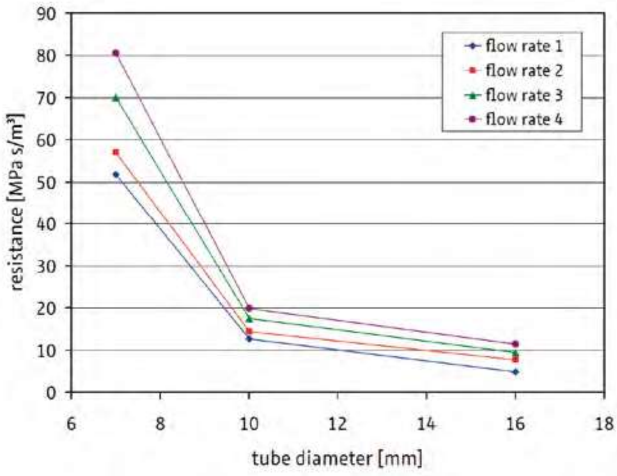


Equipment

Ultrasonic pulse Doppler FlowDop	50100
Ultrasonic probe 2 MHz	10132
Flow measuring set	50201
Standpipes	50150
Centrifugal pump MultiFlow	50130
Doppler fluid	50140
Ultrasonic gel	70200

Results

From the measured flow velocities and the respective cross section areas, the corresponding flow can be calculated. With this experiment structure, this is almost identical for all pipe diameters with the same settings of the centrifugal pump and thus fulfils the continuity equation.
As a further result, the determined flow resistance R is shown in the diagram below for different pipe diameters and for different flows. This shows the strong dependence, to be expected according to the Hagen-Poiseuille equation, on the pipe radius r: $R \sim 1/r^4$.



Related topics

Laminar and turbulent flow, continuity equation, Reynolds number, Bernoulli's equation, Hagen-Poiseuille equation, flow velocity, flow resistance, pressure scales, static and dynamic pressure, viscosity

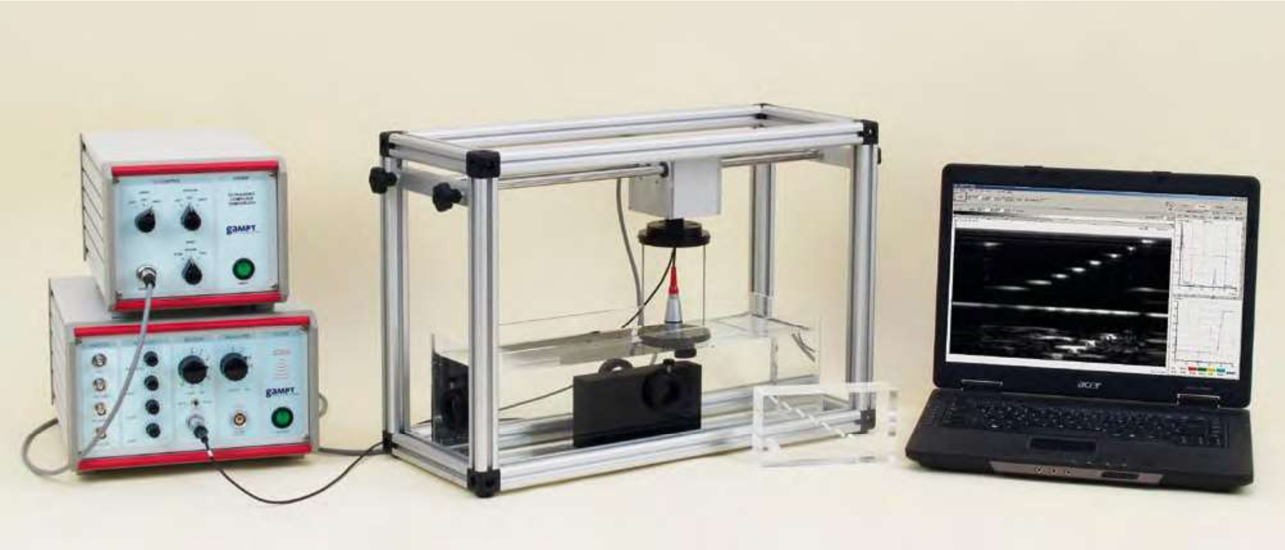
With this experiment structure, the Doppler frequency shift can be measured for different pump speeds at measurement sections with different pipe diameters. At the same time, the corresponding pressure drops can be measured by means of standpipes. In this way, it is possible to obtain clear evidence of the laws that apply to a liquid with laminar flow. From the flow velocities determined according to the Doppler method, the pipe geometries and the measured pressure drops, it is possible to determine flow rates, flow resistances and the dynamic viscosity of the Doppler liquid by formulaic application of the continuity equation, Bernoulli's equation and the Hagen-Poiseuille equation. By calculating the Reynolds numbers for the different flow velocities and pipe diameters, it is possible to check whether stationary laminar flow states were prevalent during the measurements.

Related experiments

PHY13 Ultrasonic Doppler effect
IND05 Doppler flow measurement
MED03 Basics of Doppler sonography
MED05 Vascular ultrasound (angiology)
MED06 Peripheral Doppler blood pressure measurement

PHY16 Mechanical scan methods

A computer-controlled scanner is used to record ultrasonic B-Scan images of a simple sample with two ultrasonic probes of different frequencies. The image quality of the B-Scan presentations is analysed regarding focus zone, resolution power and possible artefacts.



Related topics

Ultrasonic echography, pulse echo method, A-Scan, B-Scan, resolution power, mechanical scanning, image artefacts

To obtain a B-Scan image with an ultrasonic transducer it is necessary to shift it and/or the sound beam along the desired line for the cross-sectional image. Compared with the hand-guided approach to scanning, mechanical and electronic scanning methods offer better image quality due to a good resolution power and a freely selectable line density. Due to the low imaging frequency, however, electronic multi-element scanners are used for real-time images and moving structures. Due to the use of ultrasonic probes of different frequency in combination with mechanically guided uniform scanning, both the axial and the lateral frequency-dependent resolution power can be examined and rated in the experiment.

Equipment

Ultrasonic echoscope GS200	10400
CT scanner	60200
CT control unit UCT200	60210
Ultrasonic probe 1 MHz	10151
Ultrasonic probe 2 MHz	10152
Test block (transparent)	10201
- optional: test block (black)	10204
CT reservoir	60120
Ultrasonic gel	70200

Results

The illustration shows the B-Scan presentation of an acrylic block with drilled holes of different size and arrangement, recorded with a 2 MHz probe. By an investigation in the water bath, where the drilled holes are filled with water, echoes from both the upper edge and bottom edge of the drilled holes can be recognised. In the bottom echo, one can see the sound shadows of the holes located above.

Related experiments

PHY08 Ultrasonic B-Scan
PHY10 Characteristics of sound field
PHY20 Determination of focus zone
MED02 Ultrasonic imaging at breast phantom (mammasonography)
IND08 Detection of discontinuities

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PHY17 Acousto-optical modulation at standing waves

The acousto-optical effect of the amplitude and phase modulation of light diffracted at a standing ultrasonic wave is investigated. The effect is used to determine sound velocity in water.

Related topics

Acousto-optical effect, standing ultrasonic wave, sound wavelength, diffraction, optical grating, grating constant, amplitude modulation, phase shift

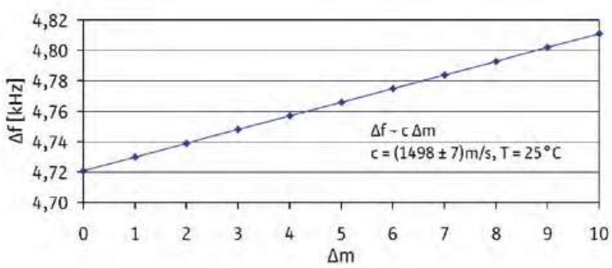
Commensurate with the Debye-Sears effect (PHY11), light is diffracted at a standing or travelling ultrasonic wave in a liquid or a solid body. The diffraction maxima produced with the diffraction at a standing ultrasonic wave are amplitude-modulated, although a phase shift of 180° occurs between the maximum of 0th and a maximum of nth order. This effect is used in acousto-optical modulators (AOMs). Using photodiodes and an oscilloscope, amplitude modulation and phase shift can be demonstrated.
A change in the sound frequency influences the modulation amplitude. The modulation amplitude is always biggest when the distance h between ultrasonic transducer and sound reflector corresponds to a multiple m of half of the sound wavelength. This makes it possible to determine the sound velocity c in the medium according to $c = 2\,h\,\Delta f / \Delta m$ (Δf: frequency difference between maximum modulation amplitudes).

Equipment

cw generator SC600	20100
Debye-Sears set	20200
Beam splitter	20301
2 adjustable reflectors	20302
2 photodiode receivers	20303
Oscilloscope	-

Results

To determine the sound velocity in water, the 0th order of diffraction is aligned to a photodiode and a first maximum amplitude is searched for. Afterwards, the sound frequency is gradually increased and the frequencies of the following maximum amplitudes are determined. For the measuring points entered in the diagram, there arises a sound velocity in water of (1498 ± 7) m/s (T = 25 °C). The laser beam is splited with a beam splitter to determine the phase shift. The second partial beam is aligned to a second photodiode so that another diffraction maximum can be obtained with it. At the oscilloscope, the phase shift between the two different orders of diffraction can be determined.



Related experiments

PHY11 Debye-Sears effect
IND04 Concentration measurement with resonance cell

PHY19 Phase and group velocity

In the experiment, the phase and group velocity of an ultrasonic wave in water is investigated. The phase velocity is measured for several frequencies in dependence on the wavelength. The group velocity is determined by the measurement of the time of flight of a short ultrasonic pulse.

Related topics

Wavelength, frequency, phase velocity, time of flight, sound pulse, group velocity, frequency dependence, dispersion

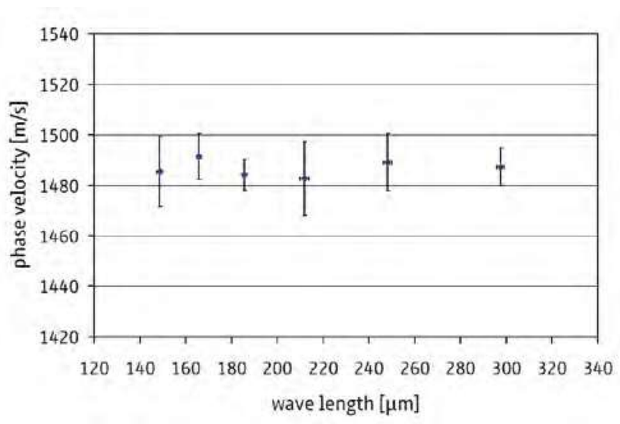
The term dispersion describes the dependence of a wave characteristic of the wavelength and/or frequency.
The characteristic/quantity investigated in the experiment is the phase velocity of an ultrasonic wave in water. For this, a hydrophone is moved along the sound axis of an ultrasonic probe. The hydrophone signal is set on an oscilloscope. By measuring the change in the probe-hydrophone distance and the respective number of phase runs at a fixed frequency f, it is possible to determine the wavelength ? and thus the phase velocity $c_P = \lambda \cdot f$. This measurement is carried out for several spacings and different frequencies.
To determine the group velocity, the ultrasonic generator is operated in pulse mode so that short ultrasonic pulses are generated from the multifrequency probe. By measuring the time of flight t of an ultrasonic pulse for a certain distance s between ultrasonic probe and hydrophone it is possible to determine the group velocity $c_G = s / t$.

Equipment

cw generator SC600	20100
Hydrophone set	10451
Multifrequency probe	20139
Ultrasonic gel	70200
Oscilloscope	-

Results

For the measurement result shown in the diagram, the phase velocity was determined at 6 different frequencies, each time for 5 different spacings between multifrequency probe and hydrophone. For water, in the investigated frequency range (5-10 MHz), no dependence of the phase velocity on the wavelength was found. A value of 1485 m/s was determined as the group velocity (time of flight of the sound pulse: 67.3 µs, probe-hydrophone spacing: 10 cm).

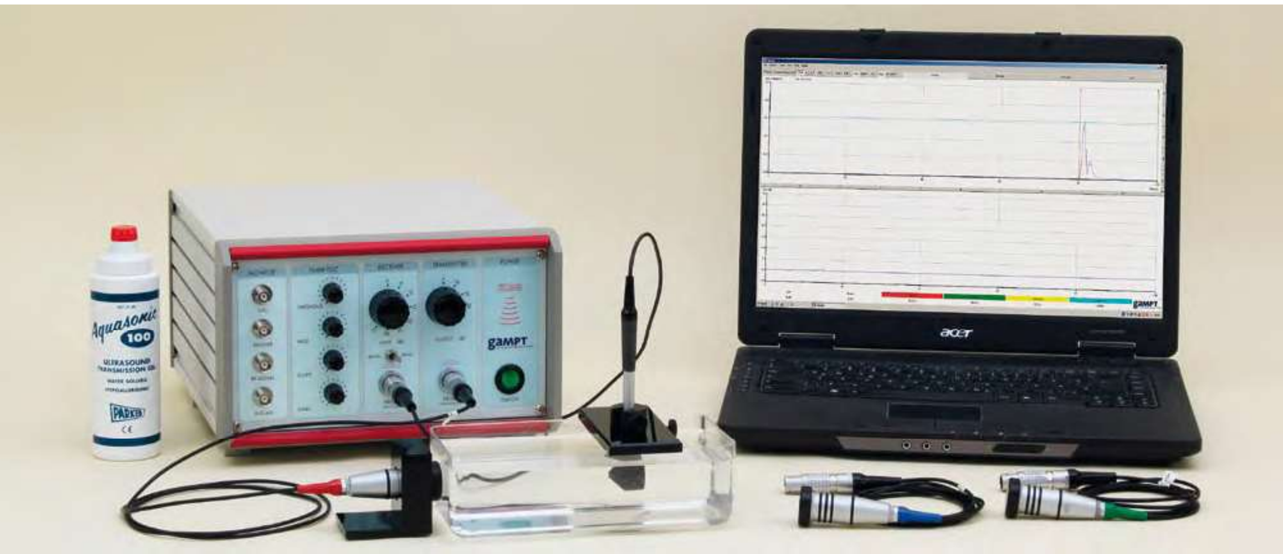


Related experiments

PHY04 Acoustic attenuation in liquids
PHY10 Characteristics of sound field
PHY20 Determination of focus zone

PHY20 Determination of focus zone

In the experiment, two ultrasonic probes of different frequency are characterised by a scanning of their sound fields with a hydrophone with regard to their near field length, focus zone and axial resolution power.



Related topics

Velocity of sound, wavelength, interference, Huygens' principle, near field, far field, near field length, focus zone, axial resolution power, hydrophone

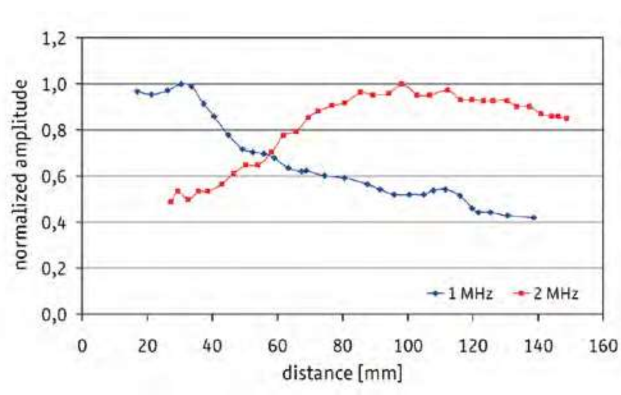
Ultrasonic probes show a different axial and lateral resolution power in dependence on their frequency. Whereas the axial resolution power is limited by the frequency of the ultrasonic probes, the lateral resolution and location of the focus zone are caused by the geometry of the sound fields. Due to interferences according to the Huygens' principle, there occurs a sound field at a round ultrasonic probe that can be divided into two areas: the near field, which shows complex conditions with strong amplitude modulations, and the far field, which appears as a sound beam with decreasing amplitude. The near field length is defined as the last maximum of the sound pressure amplitude on the acoustic axis. In the experiment, the sound pressure amplitudes for two ultrasonic probes (1 MHz and 2 MHz) are measured with a hydrophone along the sound propagation axis. From the measurement curves, the focus zones of the probes are determined and compared with the values for the near field length which can theoretically be calculated from the radii of the transducer ceramics and the wavelengths of the ultrasonic frequencies.

Equipment

Ultrasonic echoscope GS200	10400
Ultrasonic probe 1 MHz	10151
Ultrasonic probe 2 MHz	10152
Hydrophone set	10451
Ultrasonic gel	70200

Results

The calculated near field lengths with a measured sound velocity in water of 1477.64 m/s (18.5 °C) are 43.3 mm (1 MHz) and 86.6 mm (2 MHz). The values - obtained from the measurement curves - for the maxima of the signal amplitudes are approx. 30 mm (1 MHz) and 100 mm (2 MHz). More exact results are not to be expected, due to the relatively simple experiment structure. The measurements show, however, that the focus zone of the 2 MHz probe is considerably further away from the probe. The measurements are thus perfectly sufficient for the estimation of the focus area of a probe.

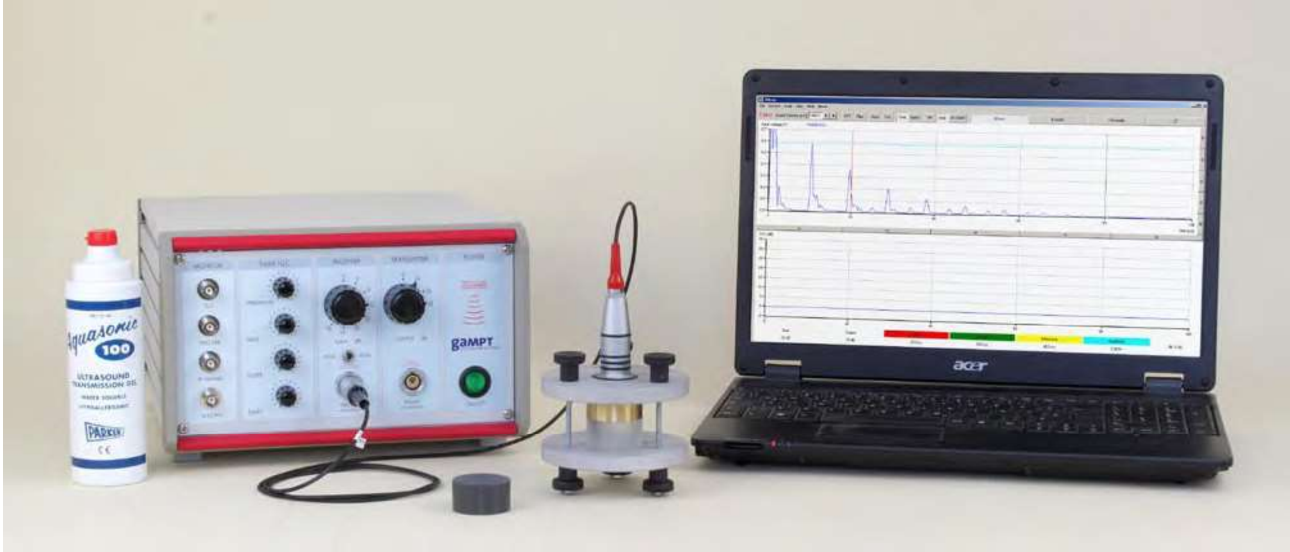


Related experiments

PHY04 Acoustic attenuation in liquids
PHY10 Characteristics of sound field
PHY19 Phase and group velocity

PHY21 Reflection and transmission at boundaries

In the experiment, the effects of reflection and transmission of ultrasonic waves at boundaries are investigated. The reflection coefficient is determined for different combinations of the materials acrylic, PVC and brass.



Related topics

Propagation of ultrasonic waves in solids, pulse echo method, reflection/transmission at boundaries, reflection coefficient, acoustic impedance, sound attenuation

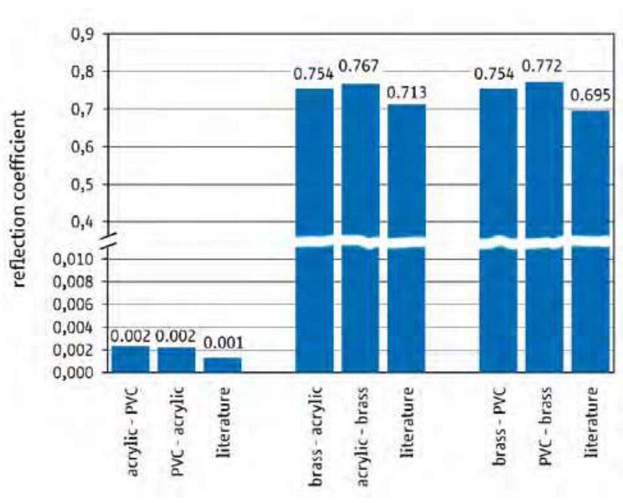
If an ultrasonic wave strikes the boundary of two materials of different characteristic acoustic impedance, it is partially or almost completely reflected. The part of reflected acoustic energy depends on the size of the difference between the characteristic acoustic impedances of the respective materials and is described by the reflection coefficient. Due to the low density and sound velocity of air, the reflection coefficient at a solid-air boundary is almost 1. Thanks to this, in the experiment the reflection coefficients for different combinations of the materials acrylic, PVC and brass can be determined by comparative measurements with the reflection coefficient against air. Furthermore, it is possible to achieve a qualitative description of the attenuation characteristics of the materials by comparing the investigated reflection echoes.

Equipment

Ultrasonic echoscope GS200	10400
Ultrasonic probe 2 MHz	10152
Acoustic impedance samples	10208
Ultrasonic gel	70200

Results

The reflection coefficients for acrylic/PVC-brass and brass-PVC/acrylic are almost the same and are probably above the theoretical values, due to a less than 100% coupling to the material junctions. The coefficients for acrylic/PVC and PVC/acrylic are almost equal and are almost zero due to the low difference between their characteristic acoustic impedances. The attenuation is lowest in brass. The largest number of multiple reflections occurs here. PVC shows the greatest attenuation, because the reflection peak of the PVC-acrylic measurement is substantially smaller with the same reflection coefficient than the reflection peak in the acrylic/PVC measurement.



Related experiments

PHY03 Acoustic attenuation in solids
PHY22 Phase shift and resonance effects
IND08 Detection of discontinuities
MED02 Ultrasonic imaging at breast phantom (mammasonography)

PHY22 Phase shift and resonance effects

In the experiment, ultrasonic signals from reflections at boundaries of different materials are recorded and analysed regarding their phase position. Furthermore, the influence of thin layers upon the reflection and transmission of ultrasonic waves is investigated using λ/4 and λ/2 plates.

Related topics

Reflection, transmission, reflection coefficient, characteristic acoustic impedance, phase shift, λ/4 and λ/2 layer

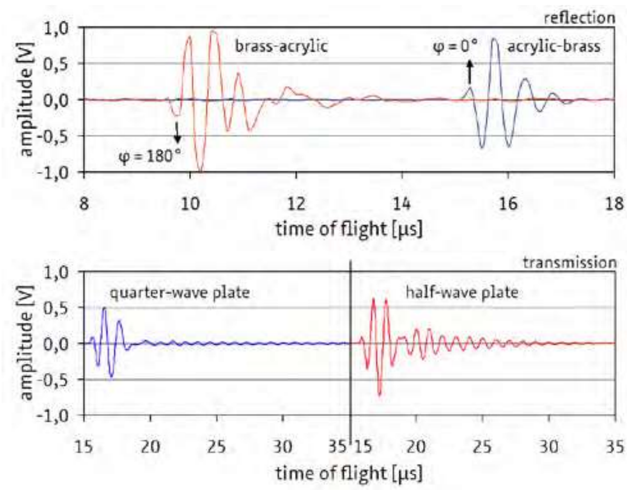
If a plane ultrasonic wave from a medium with the characteristic acoustic impedance Z_1 strikes a plane boundary to a second medium with the impedance Z_2, it is partially or completely reflected on this. The reflected part of the sound energy depends on the ratio of the impedances and is described by the reflection factor. The reflected wave generally also has another phase. In the case of perpendicular sound incidence, the phase change only takes two values: 0° for $Z_1 < Z_2$ and 180° for $Z_1 > Z_2$. Based on such a phase shift, the impedance ratio of two adjacent materials can be qualitatively described. Particularly interesting effects occur when sound passes through thin layers, the thicknesses of which are a quarter or a half of the sound wavelength. λ/4 layers are used e.g. as matching layers in order to minimise reflections and to transfer the largest possible share of sound energy from one medium into the other medium.

Equipment

Ultrasonic echoscope GS200	10400
2 ultrasonic probes 1 MHz	10151
Ultrasonic probe 2 MHz	10152
Test cylinder set	10207
Acoustic impedance samples	10208
Lambda plates	10209
Ultrasonic gel	70200

Results

The first graphic shows echo signals from an acrylic-brass and brass-acrylic boundary with perpendicular sound incidence. The characteristic acoustic impedance Z = c ρ, determined from the sound velocity c and the material density ρ, was 36.8 Mrayl for brass and 3.25 Mrayl for acrylic. The second graphic shows measurements in transmission at an acrylic cylinder. Each time, a thin aluminium plate ($c_L \approx 6309$ m/s) with a thickness of λ/4 (approx. 1.5 mm) and/or λ/2 (approx. 3.1 mm) was arranged between the transmitting probe and the cylinder.



Related experiments

PHY05 Spectral investigations
PHY21 Reflection and transmission at boundaries

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PHY23 Dispersion of ultrasonic waves (Lamb waves)

In the experiment, the phenomenon of formation and propagation of guided ultrasonic waves (Lamb waves) is investigated. The frequency-dependent velocity (dispersion) of Lamb waves in thin glass plates is measured. The Lamb waves are stimulated and determined by means of angle beam probes.

Related topics

Longitudinal waves, shear waves, Lamb waves, wave modes, phase velocity, group velocity, dispersion, law of refraction

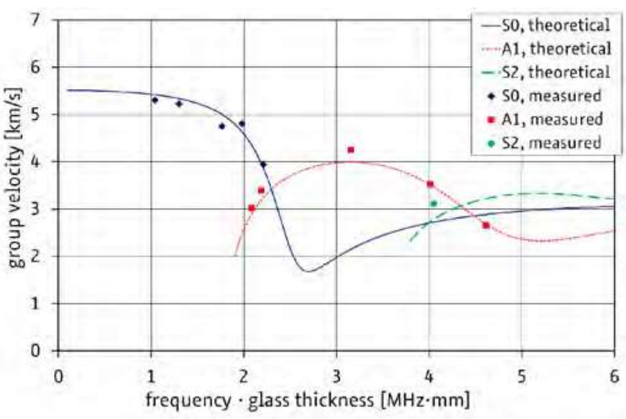
The phenomenon of Lamb waves causes by superimposing of ultrasonic transverse and shear waves in thin plates, whose thickness is smaller than the ultrasonic wave length. What is interesting about lamb waves is that they, on the one hand, show a frequency-dependent change of their propagation velocity (dispersion). On the other hand, lamb waves are present in the form of symmetrical and anti-symmetrical modes which propagate within the material independent of each other.
In the experiment, different Lamb wave modes are stimulated in thin glass plates using specific angle beam wedges and their frequency and group velocity are determined. The formation of different oscillation modes of a plate, the influence of plate thickness and the connection of Lamb waves with transverse and shear waves in conjunction with the elastic constants of the material is discussed.

Equipment

Ultrasonic echoscope GS200	10400
2 ultrasonic probes 1 MHz	10151
2 ultrasonic probes 2 MHz	10152
2 ultrasonic probes 4 MHz	10154
Lamb wave set	10300
Ultrasonic gel	70200

Results

S0, A1 and S2 modes were stimulated in the glass plates by combination of different incidence angles and sound frequencies. In the dispersion chart below, the determined group velocities are entered depending on the product of frequency and thickness of the respective glass plate. Furthermore, the chart shows the theoretical curse of curve (numerical solution) of the dispersion properties of the stimulated Lamb wave modes.

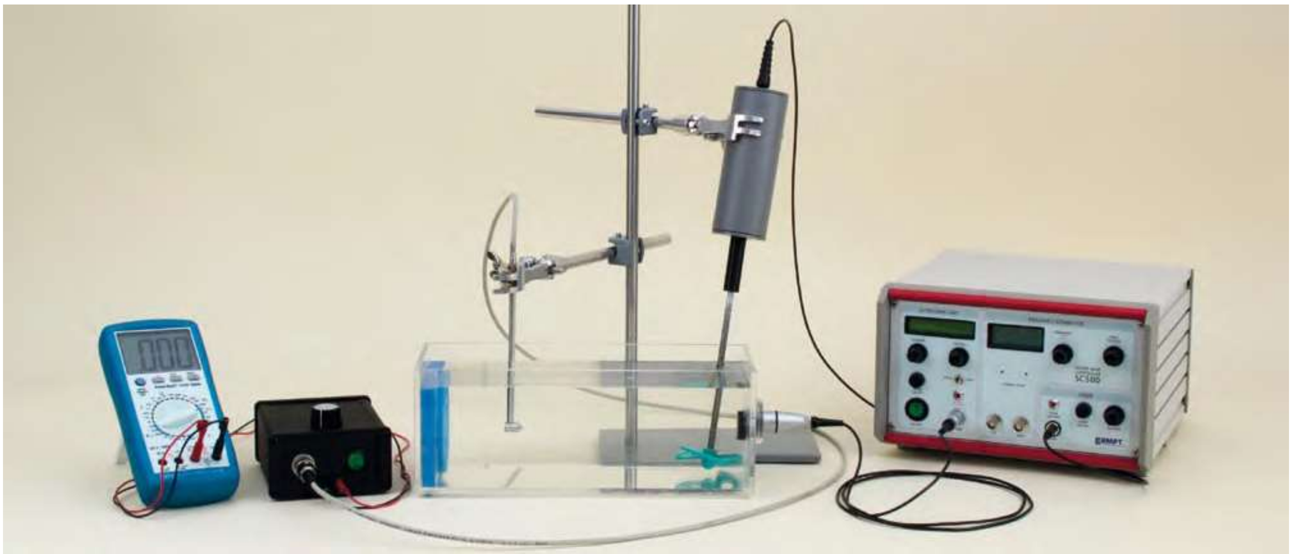


Related experiments

PHY02 Sound velocity in solids
PHY07 Shear waves in solids
PHY19 Phase and group velocity
IND02 Detection of cracks with Rayleigh waves
IND08 Detection of discontinuities

PHY24 Thermoacoustic sensor

The experiment is an introduction into the problem of the power measurement of ultrasound, using the example of the thermoacoustic sensor. The connections between the acoustic parameters and the significance of sound power measurements for dosimetry in diagnostic and therapeutic ultrasonic applications are discussed.



Related topics

Acoustic energy parameters, sound pressure, sound particle velocity, sound intensity, sound power, ultrasonic dosimetry, thermoacoustic sensor

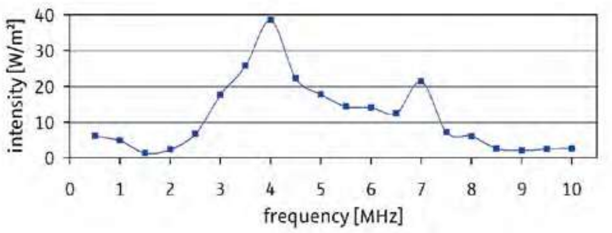
Ultrasonic intensity measurements are of decisive importance for patient safety in the quality assurance of therapeutic ultrasonic sources. The thermoacoustic sensor offers a simple option for the otherwise laborious measurements of sound intensities by means of hydrophones and acoustic radiometers. The sensor is based upon the conversion of the incident sound energy into heat inside a small absorber. This way the sound intensity can be measured as a temperature change in the absorber material by means of a thermocouple. The sensor is structured as a bridge circuit so that external temperature influences can be compensated for. The temperature change is output via an amplifier circuit as a voltage value. In the experiment, the emitted sound intensity of an ultrasonic probe is measured at different frequencies and different exciting voltages. Problems of sound generation with piezoelectric ceramics, resonance effects and propagation phenomena such as near field length and standing waves are discussed. The emitted sound intensity of the probe is calculated based upon the calibration curve of the sensor. Because the energy conversion in the sensor is frequency-dependent, the measurement values must be correspondingly corrected.

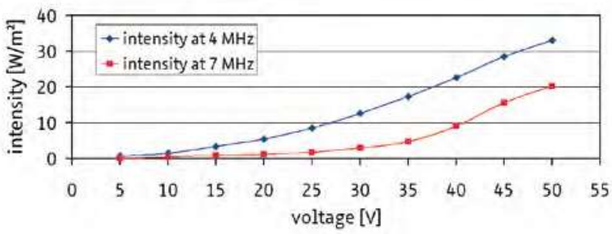
Equipment

cw generator SC600	20100
Multifrequency probe	20139
Thermoacoustic sensor	20400
Measuring reservoir	20430
Acoustic absorber	20227
Stirrer for SC500/SC600	20450
Tripod set	10310

Results

For the multifrequency probe, the sound intensities have been determined at different frequencies. The measurement shows two intensity maxima which result from the overlaying of the frequency responses of the probe and of the generator. For both resonance points, the ultrasonic intensities were measured in dependence on the exciting voltage.





Related experiments

PHY10 Characteristics of sound field
PHY20 Determination of focus zone

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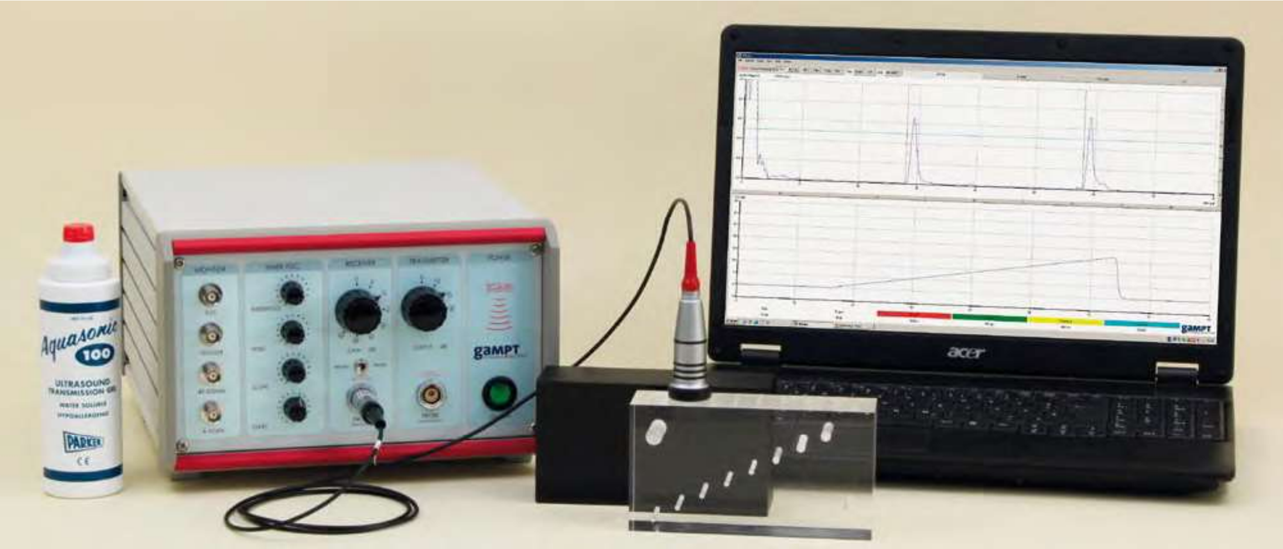
IND01 Non-Destructive Testing (NDT)

In order to localise and determine the size of discontinuities in accordance with the pulse echo method, the ultrasonic device is calibrated for a normal ultrasonic probe. For this, a DGS diagram (distance-gain-size) is compiled and a horizontal evaluation line is set in the DGS diagram for a series of equally sized replacement reflectors of different depths using time gain control (TGC).



Related topics

Sound velocity, reflection, pulse echo method, discontinuity, replacement reflector, normal probe, DGS diagram, time gain control

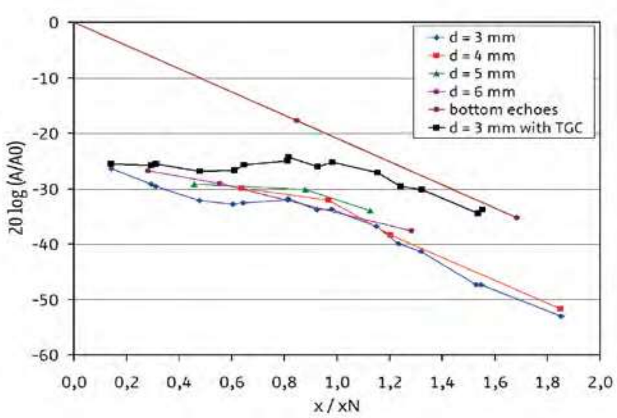
For ultrasonic tests according to the pulse echo method with perpendicular sound coupling, standard normal probes are used. The localisation of discontinuities is here carried out by reflection of the sound wave, with the time of flight of acting as a measure of the depth of the discontinuity. In contrast, an exact determination of size is usually problematic due to material attenuation and sound field characteristics. The size of discontinuities of large spatial extension can be determined by scanning. The size of small discontinuities is determined by comparison with idealised replacement reflectors from a distance-gain-size diagram. In the experiment, such a DGS diagram is to be produced using a test block with defined replacement reflectors (drilled holes of different size and depth).

Equipment

Ultrasonic echoscope GS200	10400
Ultrasonic probe 2 MHz	10152
Test block (transparent)	10201
- optional: test block (black)	10204
Ultrasonic gel	70200

Results

In the DGS diagram, the echo amplitudes of the replacement reflectors are presented in relation to the amplitude of an infinitely extended reflector in the spacing zero and its distances x relative to the zero field length x_N. For the series of the diagonally arranged, equal-sized replacement reflectors, a horizontal evaluation line was determined and entered using TGC (time gain control).

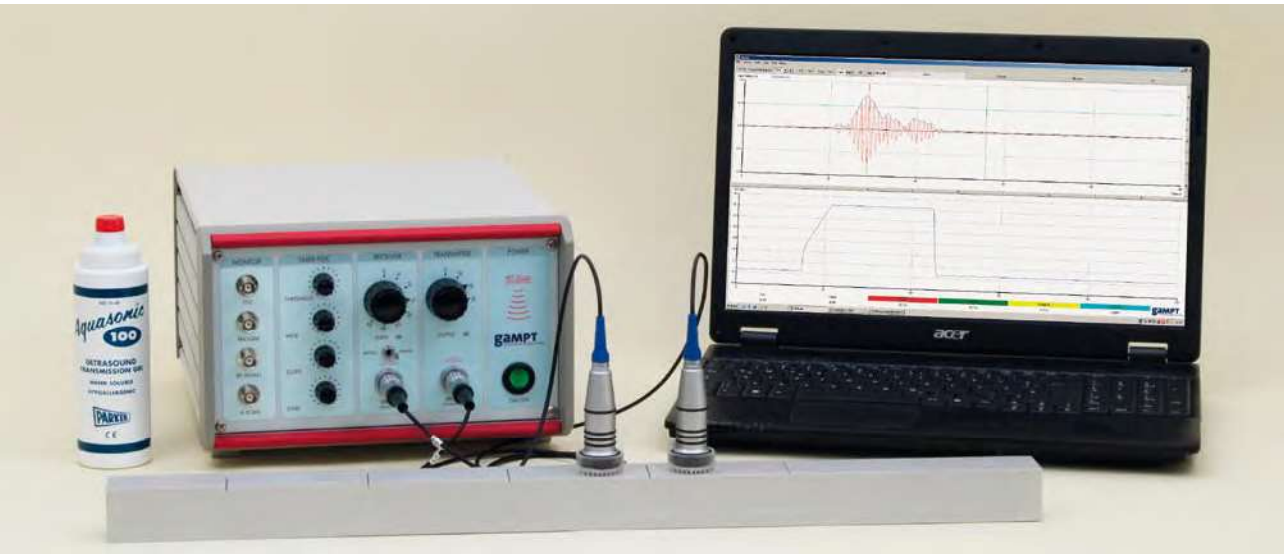


Related experiments

PHY01 Basics of pulse echo method (A-Scan)
PHY02 Sound velocity in solids
PHY06 Frequency dependence of resolution power
IND08 Detection of discontinuities

IND02 Detection of cracks with Rayleigh waves

In the experiment, the formation and propagation of Rayleigh waves is investigated. The sound velocity of the Rayleigh waves is ascertained and the dependence of the transmission amplitude of the Rayleigh waves on the crack depth is determined based on cracks of different depths.



Related topics

Longitudinal wave, surface acoustic wave, Rayleigh wave, sound velocity, sound wavelength, crack depth, reflection, transmission, mode conversion

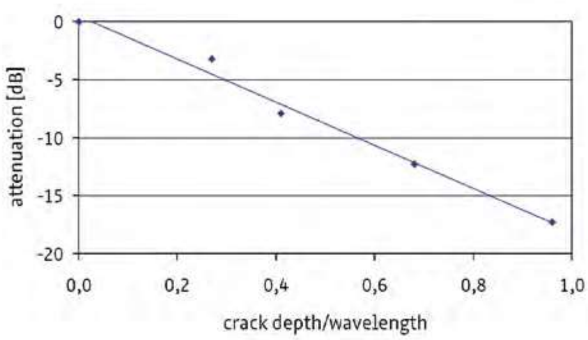
Rayleigh waves are surface waves that propagate along the free boundary of a solid. They represent a combination of longitudinal and transversal particle shifts. They can be used to detect surface faults. In the experiment, a test block with defined cracks as surface faults is investigated. The Rayleigh waves are produced by mode conversion from longitudinal waves by means of a 90° probe, where a special attachment with a comb-shaped structure is used. The velocity of the Rayleigh waves is ascertained as a difference calculation from time of flight measurements for different probe spacing. The reflection or transmission amplitude of a Rayleigh wave can be set in relation to the crack depth in the case of crack depths in the range of their wavelength. By comparing transmission amplitudes without and with crack, the crack depth can be estimated.

Equipment

Ultrasonic echoscope GS200	10400
2 ultrasonic probes 1 MHz	10151
2 Rayleigh wave attachments	10231
Rayleigh wave test block	10232
Ultrasonic gel	70200

Results

For the aluminium test block, a Rayleigh wave velocity of approx. 2920 m/s was ascertained. For the probe frequency of 1 MHz, a wavelength of approx. 2.92 mm results. For the determination of crack depth, the probes acting as transmitters and/or receivers were each placed at a distance of 5 cm away from the investigated crack. In the diagram, the attenuation of the transmission signal is entered for different crack depths; the crack depth is here entered in relation to the wavelength. For the investigated crack depth range, there results an almost linear correlation between crack depth and attenuation of the transmission amplitude, corresponding to the exponential amplitude decrease of the Rayleigh wave with the penetration depth.



Related experiments

PHY07 Shear waves in solids
IND01 Non-Destructive Testing (NDT)
IND07 Crack depth determination (TOFD)
IND08 Detection of discontinuities

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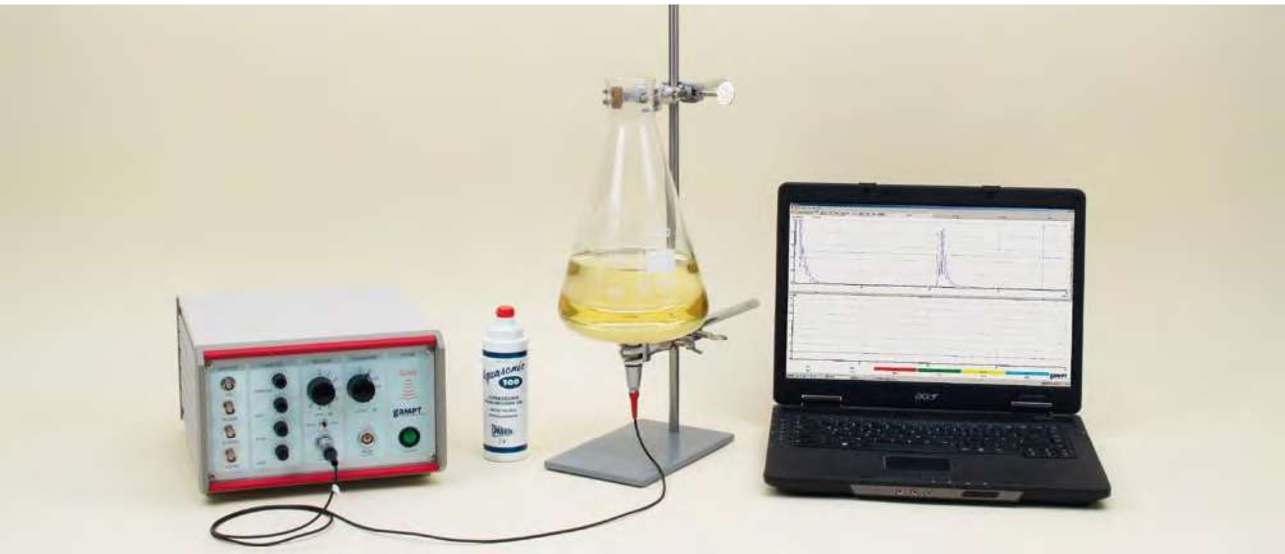
IND03 Level measurement

In the experiment, an ultrasonic level measurement is built for a two-phase liquid tank of any desired shape. A calibration curve is recorded for the filling volumes and checked on the basis of a defined fill-up. An ultrasonic limit switch is tested for the maximum tank filling.



Related topics

Sound velocity, transit time, acoustic impedance, pulse echo method, initial echo, multiple reflection, continuous measurement, limit monitoring

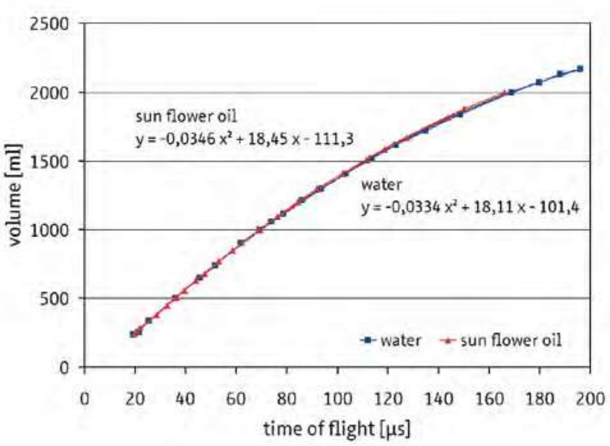
With a large number of industrial processes, especially of the automation of industrial procedures, filling level meters e.g. at tank farms, reactors, collecting tanks etc. are required. As well as different mechanical, capacitive, optical and electromagnetic sensors, in many areas ultrasonic sensors are used for level measurement. They can be used in almost any medium, including where several materials are layered on top of each other, where there is foam formation and even in very aggressive liquids, because the measurement can be carried out from outside through the container wall. In the experiment, a level measurement arrangement is configured for continuous measurements. For two different liquids (water and oil), the minimum detectable filling level is determined and a volume calibration is carried out for each. With the aid of the calibration, a level measurement is carried out on a two-layer system of the two liquids. In addition, suitable ultrasonic signals for a limit switch are recorded and analysed.

Equipment

Ultrasonic echoscope GS200	10400
Ultrasonic probe 2 MHz	10152
Tripod set	10310
Erlenmeyer flask	10330
Ultrasonic gel	70200

Results

For the calibration of the level measurement, the times of flight for different filling volumes of water and/or oil were measured. To determine any filling volumes desired, calibration curves were adapted to the measurement values. Second order polynomials sufficed as curve fits. Due to the slight difference between the sound velocities of water and of the oil used, the calibration curves here have a very similar course.



Related experiments

PHY01 Basics of pulse echo method (A-Scan)
PHY04 Acoustic attenuation in liquids
PHY21 Reflection and transmission at boundaries

IND04 Concentration measurement with resonance cell

The dependence of the sound velocity in a salt solution upon the concentration is investigated. The sound velocity in a resonance cell is measured with the aid of the acousto-optical effect of the diffraction of light at a standing ultrasonic wave.

Related topics

Sound propagation, Debye-Sears effect, standing sound wave, optical diffraction grating, wavelength, sound frequency, sound velocity, amplitude modulation, resonance cell

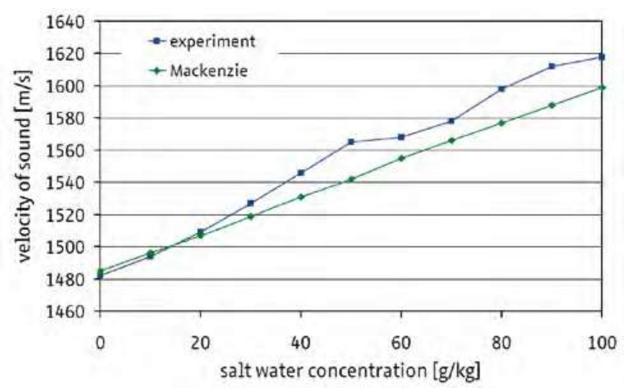
In electrolytes, when there is an increase in concentration there occurs a reduction of compressibility and an increase in the density. This leads to a concentration-dependent increase in sound velocity. The sound velocity in the electrolyte can be determined by means of the diffraction of light at a standing ultrasonic wave (PHY17). The interference maxima that are produced in the diffraction are amplitude-modulated as a result of the periodic change of the wave. The amplitude modulation takes place at twice the frequency of the standing wave. A change in the sound frequency influences the modulation amplitude. This is always biggest when the distance h between ultrasonic probe and reflector corresponds to a multiple m of the half sound wavelength. The sound velocity c in the medium can be calculated as follows: $c = 2\,h\,\Delta f / \Delta m$ (Δf: frequency difference between maximum modulation amplitudes). The measurement values are compared with values that are calculated by means of the empirical formula for sound velocity in sea water of Mackenzie (JASA, 70, 807-12).

Equipment

cw generator SC600	20100
Debye-Sears set	20200
Adjustable reflector	20302
Photodiode receiver	20303
Oscilloscope, common salt, magnetic stirrer, thermometer	-

Results

In the diagram, the measurement values and the comparative values calculated in accordance with Mackenzie's formula are entered. In the investigated concentration range, a substantial increase in sound velocity can be observed as the salt concentration is raised. In the range of 0-30 g/kg, the measurement values correspond closely to the theoretical values according to Mackenzie.

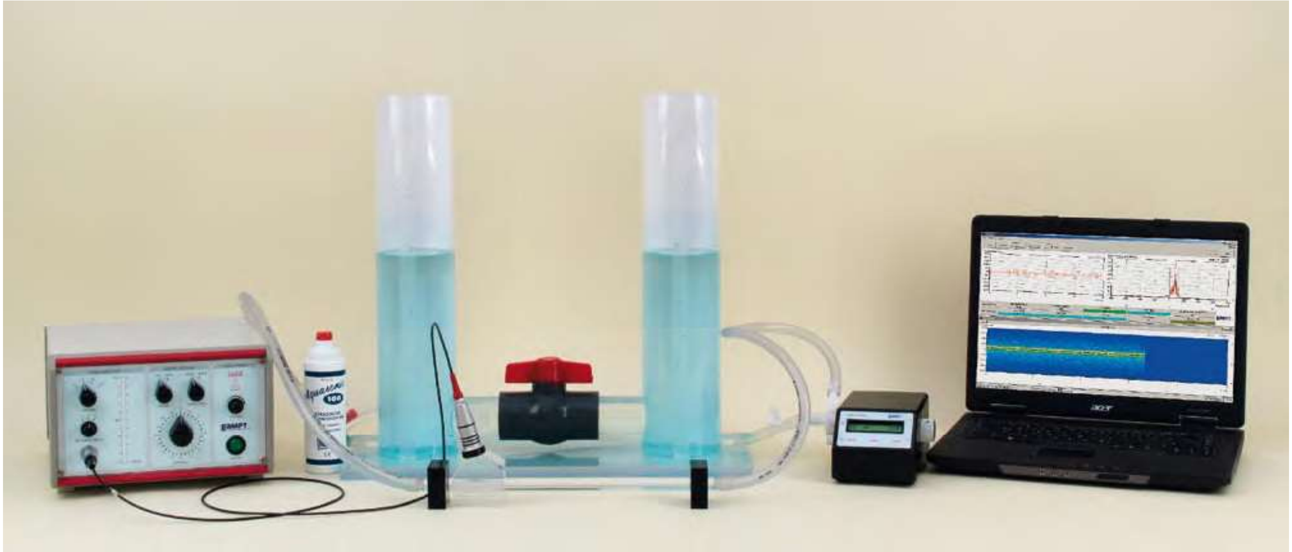


Related experiments

PHY11 Debye-Sears effect
PHY17 Acousto-optical modulation at standing waves

IND05 Doppler flow measurement

In the experiment, the dependence of the Doppler frequency on the flow for a fixed measurement arrangement as regards pipe diameter and Doppler angle is investigated. With the dependence determined, a simple flow meter is calibrated and the flow is measured while a pump is used.



Related topics

Doppler effect, Doppler frequency shift, Doppler angle, flow measurement

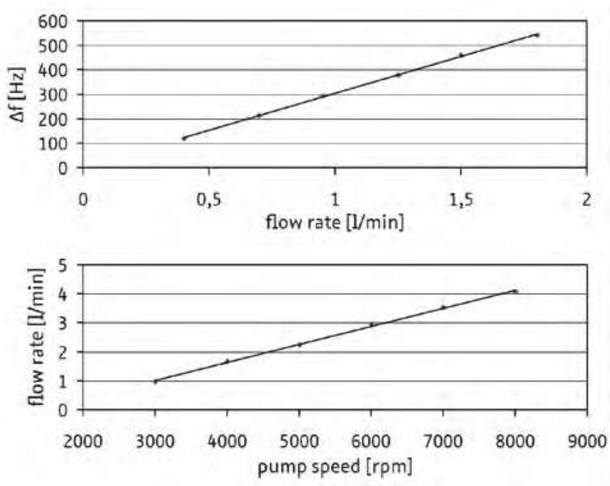
Due to the dependence of the Doppler frequency shift on the flow velocity and the proportionality between volume flow and average velocity in a fixed cross section, the Doppler effect can be used for flow measurement. The precondition is that the liquid shows a sufficient number of scatterers, in which the scattering angle is not equal to 90°. In the first part of the experiment, the Doppler frequency shift is determined for different flows of the fixed measurement arrangement, which are produced with the aid of the pump speeds. From the dependence found between flow and Doppler frequency shift there arises a calibration factor for a simple flow meter. In the second part of the experiment, different flows are produced with the pump, the respective Doppler frequency shift is measured and the volume flow is calculated for the respective pump setting with the aid of the calibration factor.

Equipment

Ultrasonic pulse Doppler FlowDop	50100
Ultrasonic probe 2 MHz	10132
Double reservoir	50170
Doppler prism 3/8“	50112
Flow pipe 3/8“	50152
Centrifugal pump MultiFlow	50130
Ultrasonic gel	70200
Timer	-

Results

In the experiment, a linear correlation is found between Doppler frequency shift and volume flow. From the increase of the linear regression lines it is possible to derive a calibration factor, using which the volume flow can be calculated for any measured Doppler frequency shift.

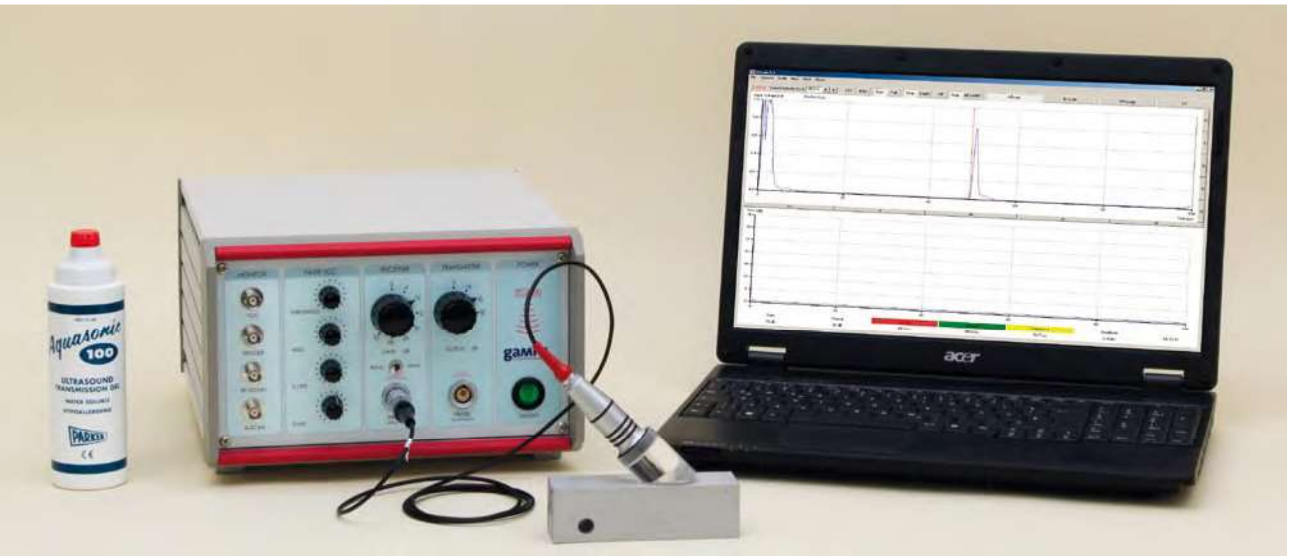


Related experiments

PHY13 Ultrasonic Doppler effect
PHY15 Fluid mechanics
MED03 Basics of Doppler sonography
MED06 Peripheral Doppler blood pressure measurement

IND06 Angle beam testing

The experiment demonstrates the use of ultrasonic angle beam probes for localising discontinuities. Measurements are carried out with delay lines with different angles of incidence, and a delay line is set for the locating of discontinuities in aluminium.



Related topics

Pulse echo method, A-scan, reflection, incidence angle, refraction angle, sound velocity, longitudinal wave, shear wave, refraction, angle echo, skip distance

Discontinuities often do not run parallel to the surface of the test object, so it is practical or even necessary to pass sound waves through at a specific angle, i.e. investigating with angle beam probes. While the calibration of normal probes for depth measurement only requires the time of flight and sound velocity, in the case of angle beam probes other geometrical factors - such as the incidence angle, the length of the delay line, the sound exit point and the additional exciting of shear waves - must be taken into account due to the oblique sound coupling. Unlike in real practice, in which standardised calibration blocks are used for calibration, in the experiment a simplified test block of aluminium is used. Due to the use of different angle beam wedges in combination with a normal probe, the ultrasonic echoes for different incidence angles can be investigated.

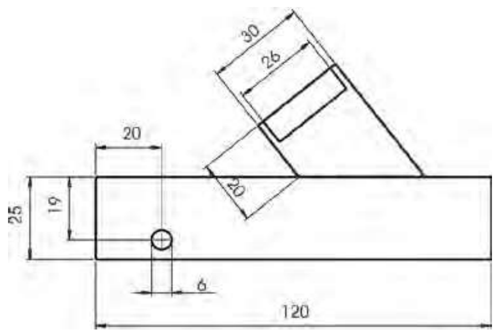
Equipment

Ultrasonic echoscope GS200	10400
Ultrasonic probe 2 MHz	10152
Angle beam wedge 38°	10234
- optional: angle beam wedge 17°	10233
- optional: angle beam wedge 56°	10235
Test block for angle beam probe	10240
Ultrasonic gel	70200

Results

For the 38° and 17° angle beam wedges and the aluminium test block, in a measurement arrangement as schematically presented in the graphic, approximately the following values occur.

Wave mode	trans.	trans.	long.	Unit
Incidence angle	38	17	17	°
Sound exit point	16.8	14.7	16.0	mm
Skip distance	48.9	36.8	46.0	mm
Refraction angle	44.5	18.5	40.7	°
Sound velocity	3091.2	3093.2	6436.6	m/s
Delay line	18,9	12.9	13.0	mm

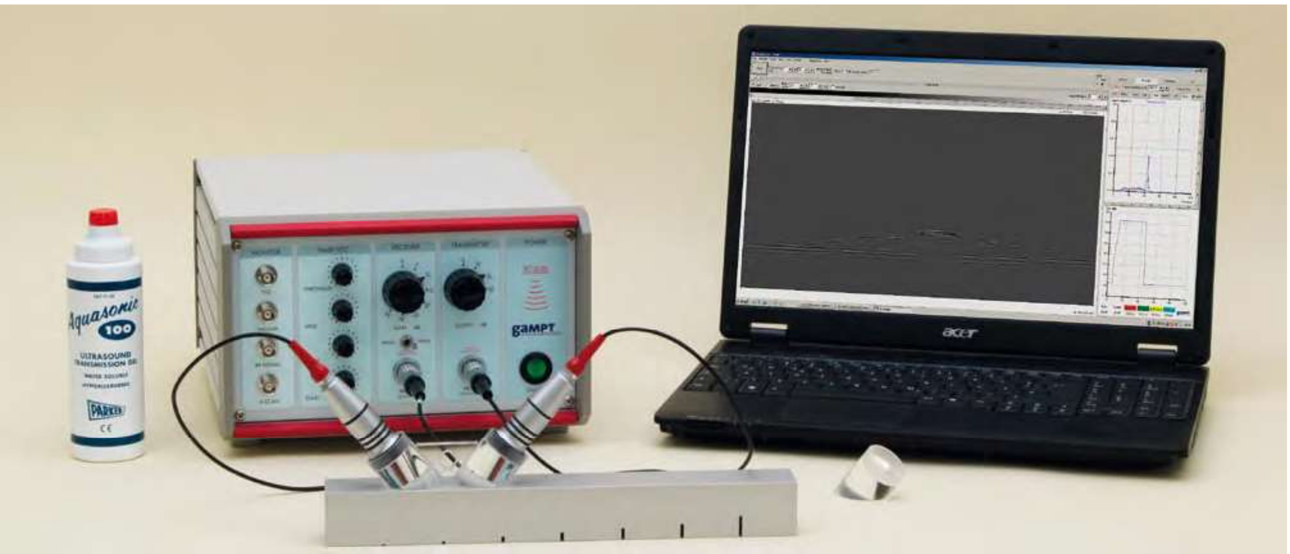


Related experiments

PHY01 Basics of pulse echo method (A-Scan)
PHY08 Ultrasonic B-Scan
IND07 Crack depth determination (TOFD)
IND08 Detection of discontinuities

IND07 Crack depth determination (TOFD)

Crack depth determination is carried out upon an aluminium test block with defined cracks. The two methods used, the echo amplitude method and the TOFD method (time of flight diffraction), are comparatively evaluated regarding their performance and detection limits.



Related topics

Non-destructive testing (NDT), sound velocity, shear waves, ultrasonic diffraction, angle beam testing, angle echo, skip distance, TOFD method, ultrasonic B-Scan

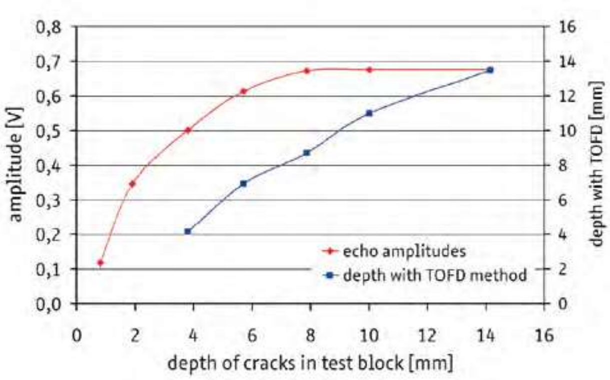
In the fracture mechanical evaluation of components regarding two-dimensional separations (cracks) accurate information is required on the defect geometry such as crack depth, crack length and crack depth position. Surface cracks can be detected with great sensitivity with angle beam probes. In this process, echoes are searched for that occur in the angle between crack and surface. Depending on the crack size and crack depth, two different methods are used which are to be investigated and evaluated in the experiment. On a test block, a) a groove characteristic line is determined for the crack depth determination in accordance with the echo amplitude method and b) the crack depths are determined with the TOFD method (time of flight diffraction). Based on the results, the suitability and sensitivity of the two methods, as regards crack geometry, can be assessed. In addition, another crack depth estimation can be carried out and analysed by recording a TOFD B-Scan image using the TOFD probe.

Equipment

Ultrasonic echoscope GS200	10400
2 ultrasonic probes 2 MHz	10152
Angle beam wedge 38°	10234
Transceiver delay line (TOFD)	10237
Crack depth test block	10241
Ultrasonic gel	70200

Results

With the echo amplitude method, with the aid of an amplitude-depth characteristic line (reference block), crack depths can be estimated that are smaller than half the diameter of the transducer (8 mm). For larger cracks, the echo amplitude moves into saturation and no longer shows any crack-depth dependence. Deeper cracks can be analysed with the TOFD method. It provides no results, however, for small crack depths (1 and 2 mm). A complete crack depth test results from the combination of both methods.

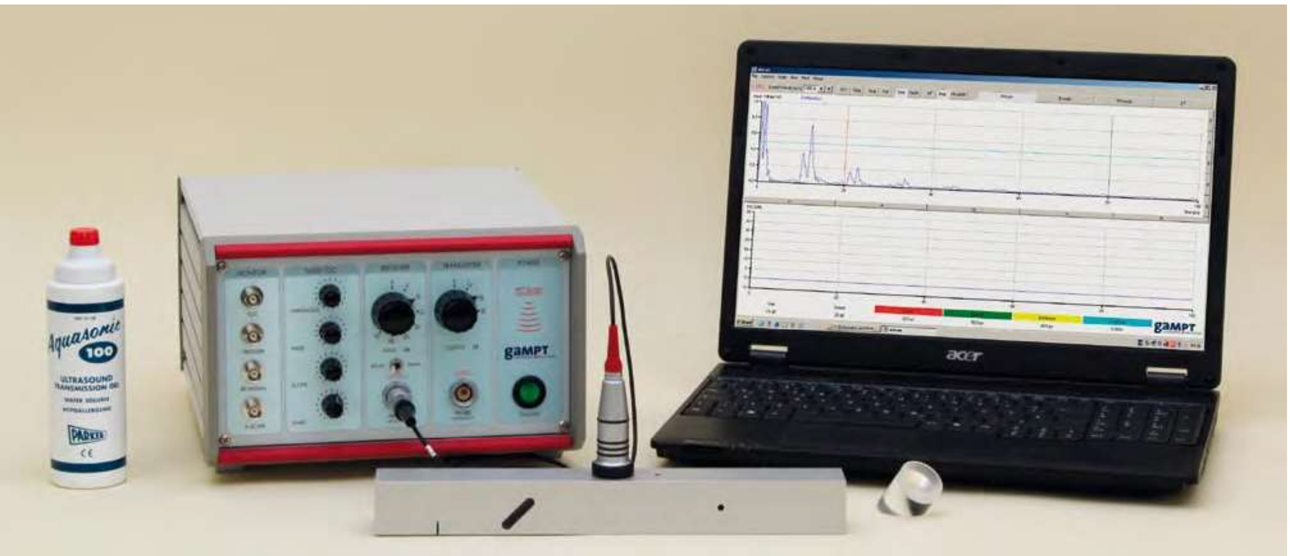


Related experiments

IND01 Non-Destructive Testing (NDT)
IND02 Detection of cracks with Rayleigh waves
IND06 Angle beam testing
IND08 Detection of discontinuities

IND08 Detection of discontinuities

Using a test block with different types of discontinuities (defects), the applicability and performance of different discontinuity locating techniques of non-destructive testing with ultrasound are analysed and the choice of the correct locating technique for specific testing tasks is discussed.



Related topics

Ultrasonic echography, discontinuity, reflection, incidence angle, refraction angle, A-Scan, B-Scan, normal probe, angle beam probe, signal-to-noise ratio

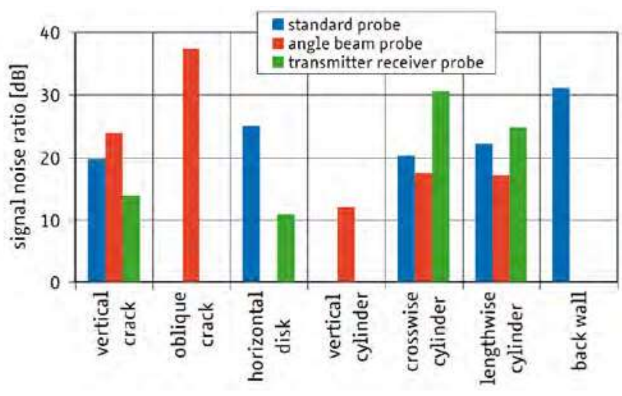
Different methods of locating and size determination are necessary depending on the type of discontinuity. In the experiment, a test block with idealised discontinuities is investigated with a normal probe, an angle beam probe and a transmitter-receiver probe (TR or dual-element probe). B-Scan images of the test block are recorded with each probe and analysed. In a second series of tests, the signal-to-noise ratio for the discontinuities found is determined with each probe. Based on the results, the detectability of the discontinuity types with the individual locating methods is evaluated and their selection is discussed as regards special test tasks of practical application.

Equipment

Ultrasonic echoscope GS200	10400
2 ultrasonic probes 2 MHz	10152
Angle beam wedge 38°	10234
Transceiver delay line (TOFD)	10237
Discontinuity test block	10242
Ultrasonic gel	70200

Results

The results summarised in the diagram show that different discontinuity types require differentiated locating methods. For example, small discontinuities can only be located by the analysis of the scattering signals with the transmitter-receiver probe. From the oblique crack, one can only receive an echo signal with the angle beam probe, and from the back wall only with the normal probe. In addition, the boundaries of the modelled discontinuities become clear. So in practice, a perpendicular crack will not be detectable with the normal probe or will be substantially more difficult to detect than the saw cut in the test block intended to model such a crack.



Related experiments

PHY08 Ultrasonic B-Scan
IND01 Non-Destructive Testing (NDT)
IND06 Angle beam testing
IND07 Crack depth determination (TOFD)

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