Basics

Ultrasonic Testing

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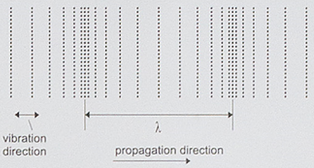
Why ultrasonics?

Ultrasound denotes all soundwaves with a frequency higher than audible (approx. 16 kHz). For nondestructive testing (NDT), it is important, that ultrasonic waves can penetrate almost every material and that the wave reflects at interfaces of different material, respectively transmits with a lower intensity. Ultrasound is usually applied for the detection of internal flaws (volume testing method). The wavelength λ determines the smallest detectable flaw.

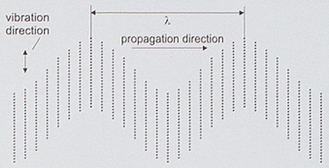
$$\lambda = \frac{\text{c (sound velocity)}}{\text{f (frequency)}}$$

longitudinal wave
propagates with c_l



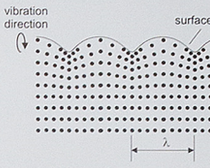
Propagation direction and vibration direction are parallel to each other for longitudinal waves

transversal wave
propagates with c_t



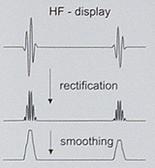
Propagation direction and vibration direction are perpendicular to each other for transversal waves (transversal waves do not exist in gaseous and liquid material)

Rayleigh wave (surface wave)
propagates with c_R



Other wave-types apear at surfaces and interfaces (e.g. surface waves)

screen display



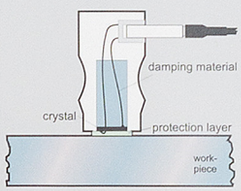
A-scan of an ultrasonic instrument (flaw detector)

Probes

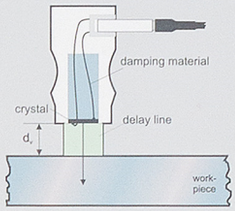
Probes (also called transducers) are used for transmitting ultrasound and receiving the reflected sound wave. Inside the probe housing a crystal, which convert an electrical pulse into an ultrasonic wave and later an ultrasonic wave back into an electrical pulse. The resonance frequency of the crystal is the testing frequency of the probe.

For the different testing tasks different types of probes exist:

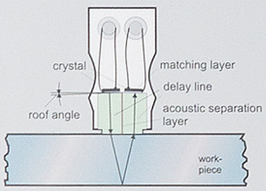
normal probe
standard



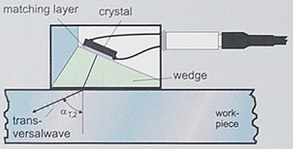
probe with delay line
thin workpieces, wallthickness



TR-probe
thin workieces, wallthickness



angle probe
weld testing

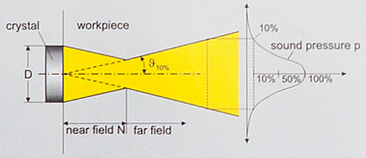


The sound field of a probe

The sound field of a probe can be divided into the near field (direct infront of the probe) and the far field. The length of the near field and the divergence angle are determined by the frequency f and the crystal diameter D.

The inspection is carried out in the far field of the probe.

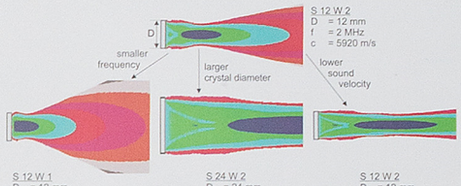
sound field of a probe



$$N = \frac{f D^2}{4c} \qquad \sin \vartheta_{10\%} = 0{,}87 \frac{c}{f D}$$

c = sound velocity in workpiece
f = frequency
$\vartheta_{10\%}$ = divergence angle (by a drop down to 10%)
D = crystal diameter
(often used: D_{eff} = 0,95 D)

influences to the sound field



S 12 W 2
D = 12 mm
f = 2 MHz
c = 5920 m/s

S 12 W 1
D = 12 mm
f = 1 MHz
c = 5920 m/s

S 24 W 2
D = 24 mm
f = 2 MHz
c = 5920 m/s

S 12 W 2
D = 12 mm
f = 2 MHz
c = 2730 m/s

sound velocities and densities

material	c_l (m/s)	c_t (m/s)	ρ (g/cm³)
aluminium	6200-6400	3130	2,7
lead	2160-2400	700	11,3-11,4
iron	5850-5900	3230	7,7-7,86
epoxide resin	2400-2900	1100	1,1-1,25
cast iron	3500-5800	2200-3200	6,9-7,3
copper	4600-4750	2260-2300	8,9
brass (Ms 58)	3830-4250	2050-2200	8,1-8,5
nickel	5600-5894	2960-3219	8,8
oil (20 °C)	1200-1750	-	0,8-0,89
perspex	2730	1430	1,18
polyethylen (PE)	1950-2000	540	0,9
polypropylen (PP)	2404	1035	0,9
quartz glass	5570	3520	2,6
silver	3600-3790	1590-1760	10,5
steel (calibration block)	5920	3255	7,7-7,86
teflon	1350	550	2,2
titanium	5823-6260	2920-3215	4,5
water (20 °C)	1483	-	1,0
zinc	4120-4170	2350-2410	7,1
tin	3210-3320	1530-1670	7,3

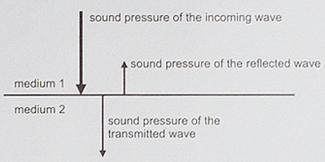
Coupling, reflection and refraction

Ultrasonic testing is mainly used for the detection of internal flaws inside a workpiece with use of the contact testing technique. The good reflection of ultrasonic waves at an interface workpiece - air (e.g. steel - air) is very helpful for the detection of internal flaws. By evaluating such reflections, inclusions of air and cracks are easy to detect.

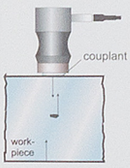
Ultrasonic waves in the MHz-frequency range do not propagate in air. For the transmitting of the waves from the crystal to the workpiece a coupling medium is used (water, oil, gel, ...).

Transversal waves propagate only in solid workpieces.

interfaces (normal incidence)

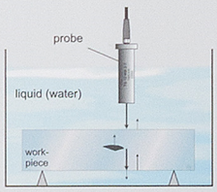


contact testing technique
(manual testing)



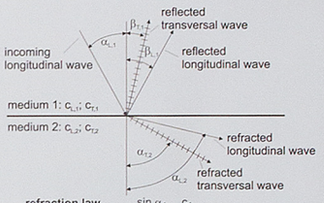
Coupling with some coupling medium.

immersion technique



Coupling with water (or other liquids). The workpiece is completely immersed into water.

interface (angled incidence)



refraction law of Snellius: $\frac{\sin \alpha_1}{\sin \alpha_2} = \frac{c_1}{c_2}$

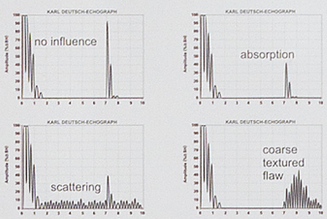
Applications

Ultrasonic testing is applicable for the detection of internal flaws like inclusions and cracks, often for weld testing. But it is also applicable for the measurement of

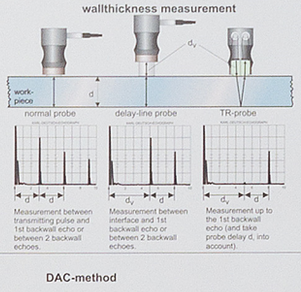
- wallthickness,
- sound velocity,
- flow velocity of liquids in pipes and blood in blood vessels,
- hardness testing,
- ....

Moreover it is also used in the quality control of cast iron.

some possible material influences



wallthickness measurement

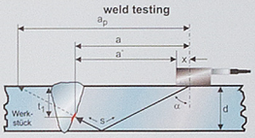


Measurement between transmitting pulse and 1st backwall echo or between 2 backwall echoes.

Measurement between interface and 1st backwall echo or between 2 backwall echoes.

Measurement up to the 1st backwall echo (and take probe delay d_v into account).

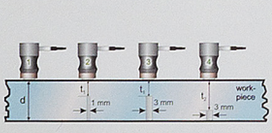
weld testing

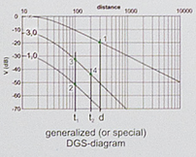


a	= s sin(α)	= projection distance	s = sound path
a'	= a - x	= shortened projection distance (distance to flaw)	a_p = 2d tan(α) = skip distance
t_i	= 2d - s cos(α)	= depth of the flaw	α = angle of refraction (angle of the probe)
d		= wallthickness	x = index front distance

Evaluation methods for the echo height

DGS-method



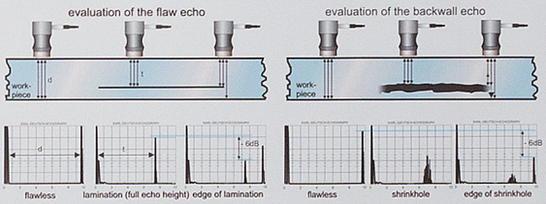


The DGS-method is applicable to flaws which are smaller than the sound beam diameter. Series of curves which show the relationship between distance along a beam and gain in dB for an infinite reflector (backwall) and different sizes of disc shaped reflectors (flat bottom holes). The echo height will be evaluated by this series of curves.

DAC-method

The DAC-method is applicable to flaws which are smaller than the sound beam diameter. A reference curve is constructed (measured) on the basis of peak echo amplitudes from a reference reflector (often side-drilled holes) at varying distances from the probe. The echo height will be evaluated by this DAC-curve.

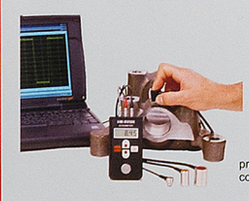
half-amplitude-method



The half-amplitude-method is applicable to flaws which are greater than the sound beam diameter. The flaw size will be evaluated by determination of the flaw edges (6 dB decrease of the flaw echo or the backwall echo).

ECHOMETER

wallthickness gauge



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For more than 50 years instruments, sensors and systems for NDT: ultrasonics · wallthickness measurement · probes · coating thickness measurement · magnetic particle testing · penetration testing · crack depth measurement · material sorting

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