# Ultrasonic transducers and typical applications

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## Abstract

Ultrasonic probes, which are applied in the field of nondestructive testing ( NDT ), are generally based on piezoelectric transducers.

The applications range from concrete testing with low sound frequencies around 100 kHz to the inspection of small and fine grained objects, e.g. spot welds of car bodies, with frequencies around 20 MHz.

This presentation contains a probe overview and a description of three application examples:

- Ultrasonic testing of refractory bricks
- Spot weld inspection
- Tube inspection with phased arrays

## Ultrasonic probes

Standard probes, as shown in figure 1, are used for the measurement of thicknesses and for the flaw detection in objects, like castings, forged material or welded seams of tubes and vessels. In accordance to the inspection task we use either longitudinal waves for perpendicular insonification and transverse waves for the inspection with angle probes. Such probes are used for manual inspections with a direct coupling.

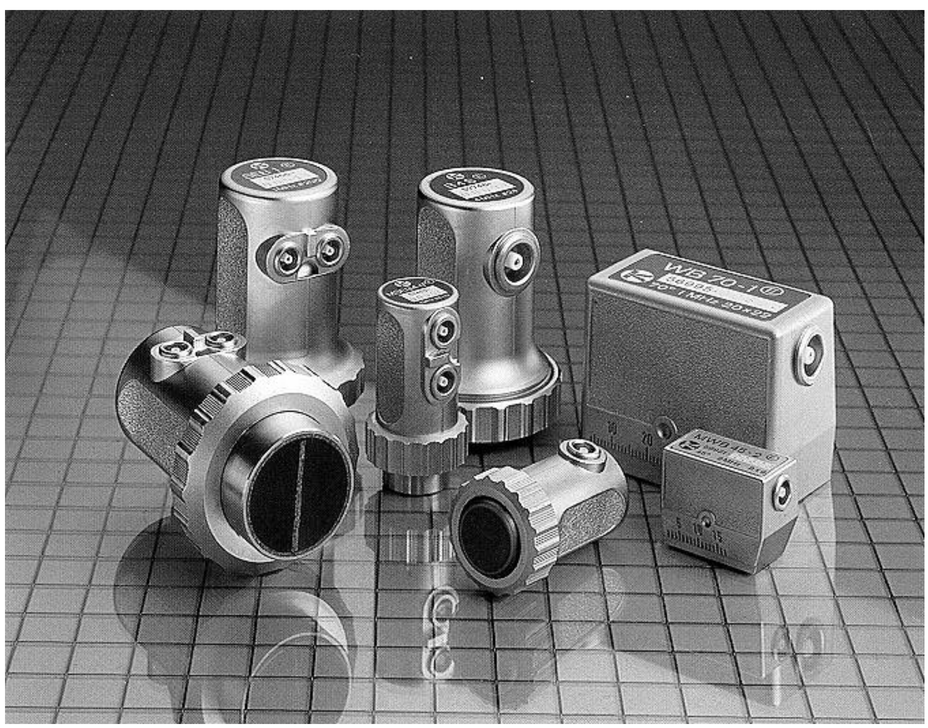



**Fig. 1: Standard Probes for direct coupling**

In case of automatic inspection with testing machines immersion probes are used according to figure 2 or squirter probes as shown in figure 3.

**Fig. 2: Probes for immersion technique**

**Fig. 3: Sqirter Probes**

In general, the typical transducer materials are monolitic piezoelectric ceramics or, if higher spectral bandwidths are required, also composite transducers.

In case of higher frequencies we use PVDF transducers (Polyvinildifluoride), see figure 4. The PVDF foils can be manufactured extremely thin in order to obtain high frequencies above 20 MHz. Furthermore the foils are flexible, thus enabling us to form focussed sound beams.

**Fig. 4: PVDF Immersion Probes**

Nevertheless, these examples are only a small selection of available probes. For the many kinds of applications in the different industries, today thousands of different probes are in use, with different frequencies, bandwidths, diameters and geometries.

## Example 1: Ultrasonic inspection of refractory bricks

The first example concerns the inspection of refractory bricks as used in the blast furnaces of the steel industry.

The inspection task is to measure the length of the brick in built in condition. That means, that only one end is accessible.

Furthermore cracks shall be detected. For this purpose an artificial crack in the form of a saw notch was cut into the brick.

To solve this inspection problem we recommend to apply the 200 kHz probe G0.2R1, which provides high power and a large bandwidth, which is necessary to obtain echo signals with a good axial resolution. In figure 6 an echo is shown in the time and the frequency domain.

As can be seen in the A-Scans of figure 7, both, the echo of the crack and the backwall can easily be detected with a good signal to noise ratio.

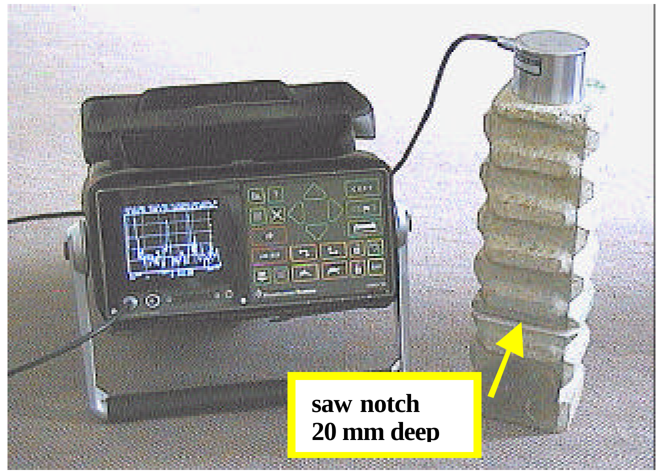



**Fig. 5: Inspection of a refractory brick**

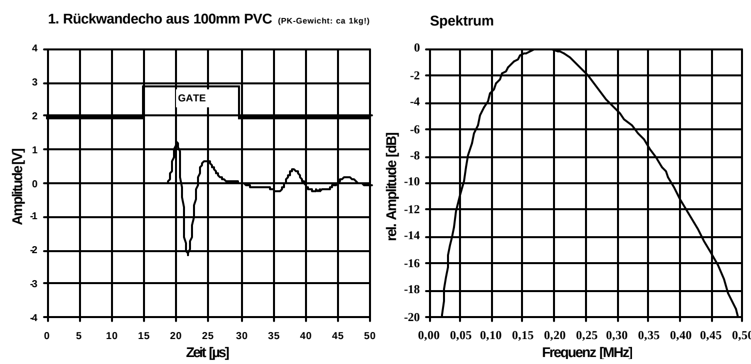
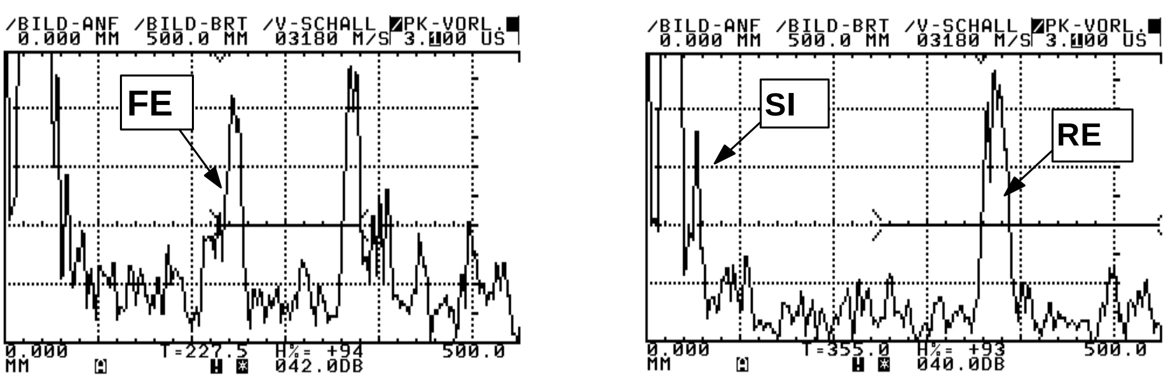



**Fig. 6: Echo of G0.2R1 probe and it‘s spectrum**




*Crack detection at 227 mm depth*

*Measurement of brick length*

**Fig. 7: A-Scan Results of brick inspection**

**Example 2: Ultrasonic spot weld inspection**

The computer aided spot weld inspection, see figure 8, has achieved a high state of art and is applied by almost all car manufacturers in the world.

For this purpose, a special ultrasonic probe was developed as shown in figure 9. The probe contains a PVDF transducer for 20 MHz, thus performing a wavelength in steel of 0,3 mm.

In order to enable always a good coupling, which is critical because of the electrode indentations, the probe housing contains a water column with a flexible membrane at the end. This ensures a good coupling even in case of critical indentation geometries.

The inspection principle is demonstrated in figure 10:

In case of a good spot weld [1] we obtain an echo sequence as shown. Due to the coarse grained material and the related sound attenuation at 20 MHz the echo sequence decays quickly.

If the spot is too small [2], the echo sequence contains additionally intermediate echoes due to the fact that the sound field diameter is larger than the spot diameter. The required spot nugget diameters depend from the thickness of the steel plates and therefore different probes with different transducer diameters have to be used. In order to avoid human errors, the probes are designed as dialog probes, so that the computer always recognizes the actual probe.

A stick joint [3] is transparent for the sound but the lower sound attenuation leads to a longer echo sequence.

Finally, if there is no joint at all [4], one obtains an echo sequence from the first plate only.

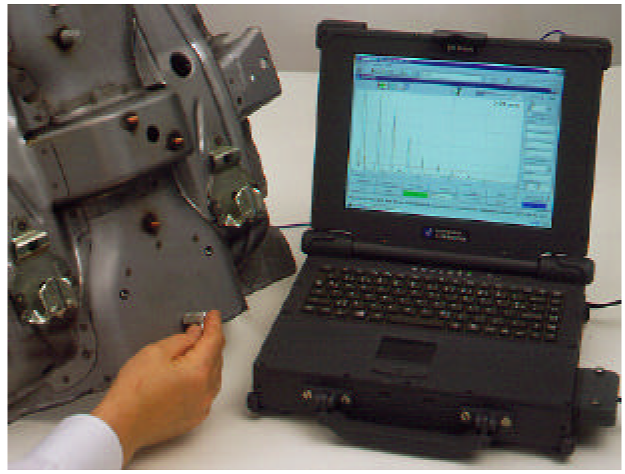


**Fig. 8: Spot Weld Inspection**

**Fig 9: Spot Weld Probe**

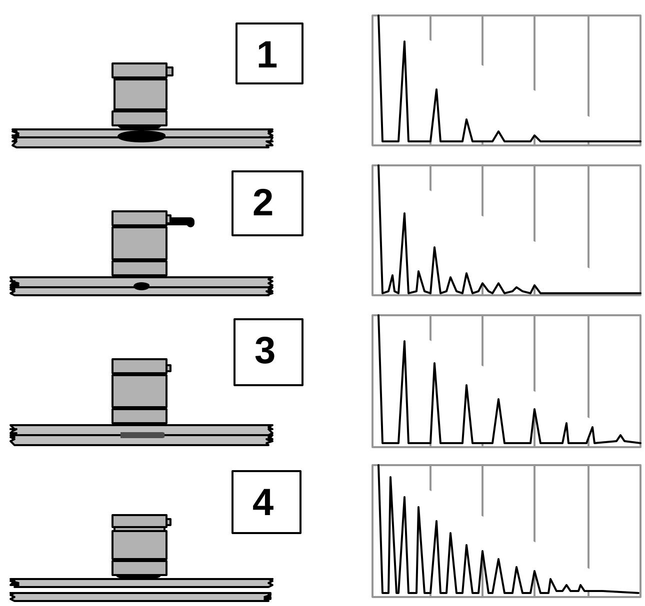



**Fig. 10: The principle of spot weld inspection**

**Example 3: Tube inspecion with Phased Arrays**

A modern tool in the field of NDT is the Phased Array Technique. Arrays consist of a number of single elements, which can be excited with time and amplitude modulations. This allows

- an electronical indexing, which replaces an mechanical probe shift by electronical scanning.
- an electronical steering, which enables an angular sweep of the sound beam
- an electronical focussing, which allows to set the focus of the sound beam at variable depths.

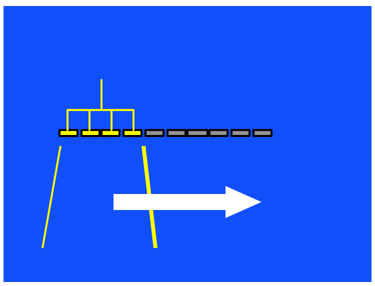


**Fig. 11: Electronic indexing**

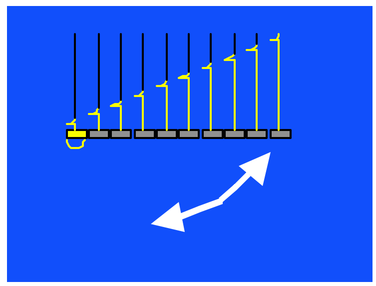


**Fig. 12: Electronical steering**

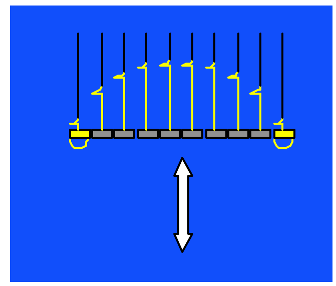


**Fig. 13: Electronical focussing**

For the inspection of tubes, i.e. the measurement of thickness and the inspection of longitudinal weld seams, a special array probe was developed as shown in the figures 14 and 15. The technique implies all the three above mentioned methods.

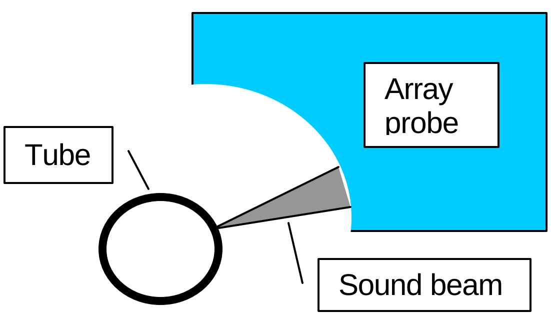



**Fig. 14: Phased Array Probe for tube inspection**

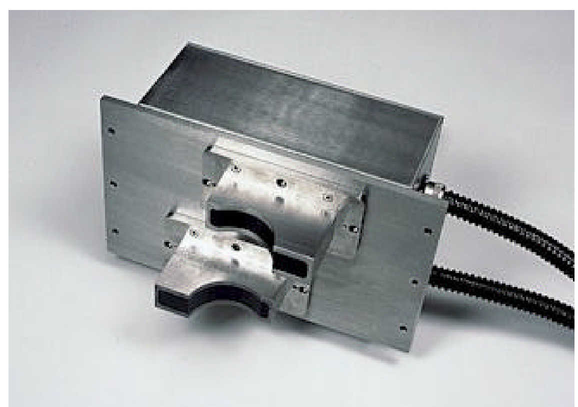


**Fig. 15: Phased Array Probe for tube inspection**

The Phased Array probe for tube inspection as shown in Fig. 15 contains 2 x 128 elements with a width of 0.48mm and a gap of 0.05 mm. The length is 10 mm and the radius 45 mm. The probe operates at 6.5 MHz. The tubes which can be inspected by means of this probe system lie in the diameter range from 20 to 65 mm and a thickness range between 1 and 8 mm.