Visualisation and Evaluation of Phased Array UT Data

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Abstract. The inspection of components with high safety requirements demands the application of advanced nondestructive testing techniques as well as modern equipment with the means for data collection and a high storage capability. Furthermore, in accordance with the component specifications, an objective data evaluation is needed so that human factors are minimised. This can be achieved by data visualisation starting from the "simple" A-scan presentation with some evaluation tools up to presentations using reconstruction algorithms such as Synthetic Aperture Focusing Technique (SAFT).

In the past, various evaluation program tools were developed, or optimized in the ultrasonic working groups at BAM, often in connection with modern ultrasonic methods such as the phased array technique. Especially in the field of inspection for heavy components commonly encountered in the nuclear field, advanced evaluation and data presentation programs are necessary for handling the high data rate. The other very important point is the reliability of the evaluation results. In some cases these results are the basis for the quantification of defects using fracture mechanics algorithm. In the present contribution the simple A-scan presentation, B-, und C-Scan presentation, the use of sector scan presentation for typical application, SAFT–Data presentation and the application of echotomography will be discussed.

1. Introduction

Visualisation means: position related representation of indications coming from different index points deliver indications, which are presented as distribution of signals resulting as echo dynamic.

Perturbation signals do not show such a characteristic echo dynamic and this feature is used for a filtering process to clear flaw signals from false signals. The basis of the measurement data is the A-scan, which is always used for evaluation.

Graphic screen representation is managed in such a way, that an A-scan is faded in the reconstruction image together with probe position, direction of incidence and soundpath-region. In four examples different visualisations of UT data are shown.

2. Tomographic representations of a forged turbine shaft

Measurement results of a turbine shaft (length approx. 8 m, diameter 1,665 mm, production gross weight approx. 120 t) showing flaws detected by a mechanized ultrasonic testing are used for tomographic reconstruction. Ultrasonic measurements at the turbine shaft were executed with a phased array straight beam probe equipped with a plexiglass wedge adapted to a shaft curvature radius of 828 mm. The inspected region covered a length of 2,3 m. The probe was helically guided on the cylindrical surface in circumferential direction. Per rotation the probe covered a distance of approx. 25 mm in axial direction. The distance between adjacent measurement points had an amount of 1,5°. In 13 measurement functions a phased

array beam scan area from - 21° to +21° was realized. For each rotation an ultrasonic tomogram was reconstructed. A side view of all tomograms shows the whole inspection area in axial direction.
Echo amplitudes are represented in terms of colour by a preadjusted colour scale. Thereby indicated and recorded findings are quickly recognized.

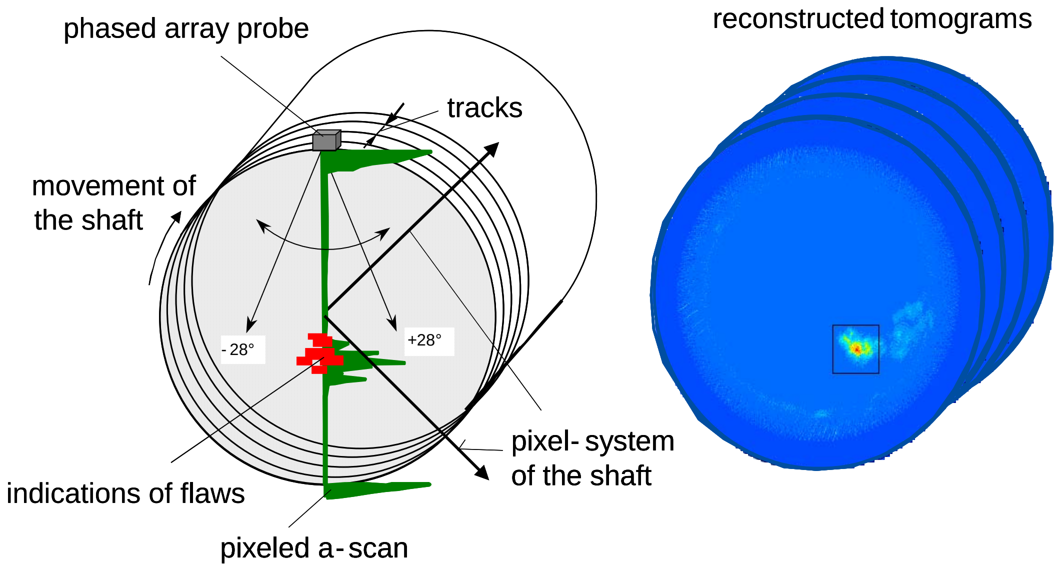


Fig. 1: Cross section picture of the shaft

With the help of a mouse pointer an intersection line may be selected and the related tomogram is then represented. In the tomogram defined areas may be zoomed by a lens function and then geometric position and amplitude height of single indications may be analyzed (see Fig.2).

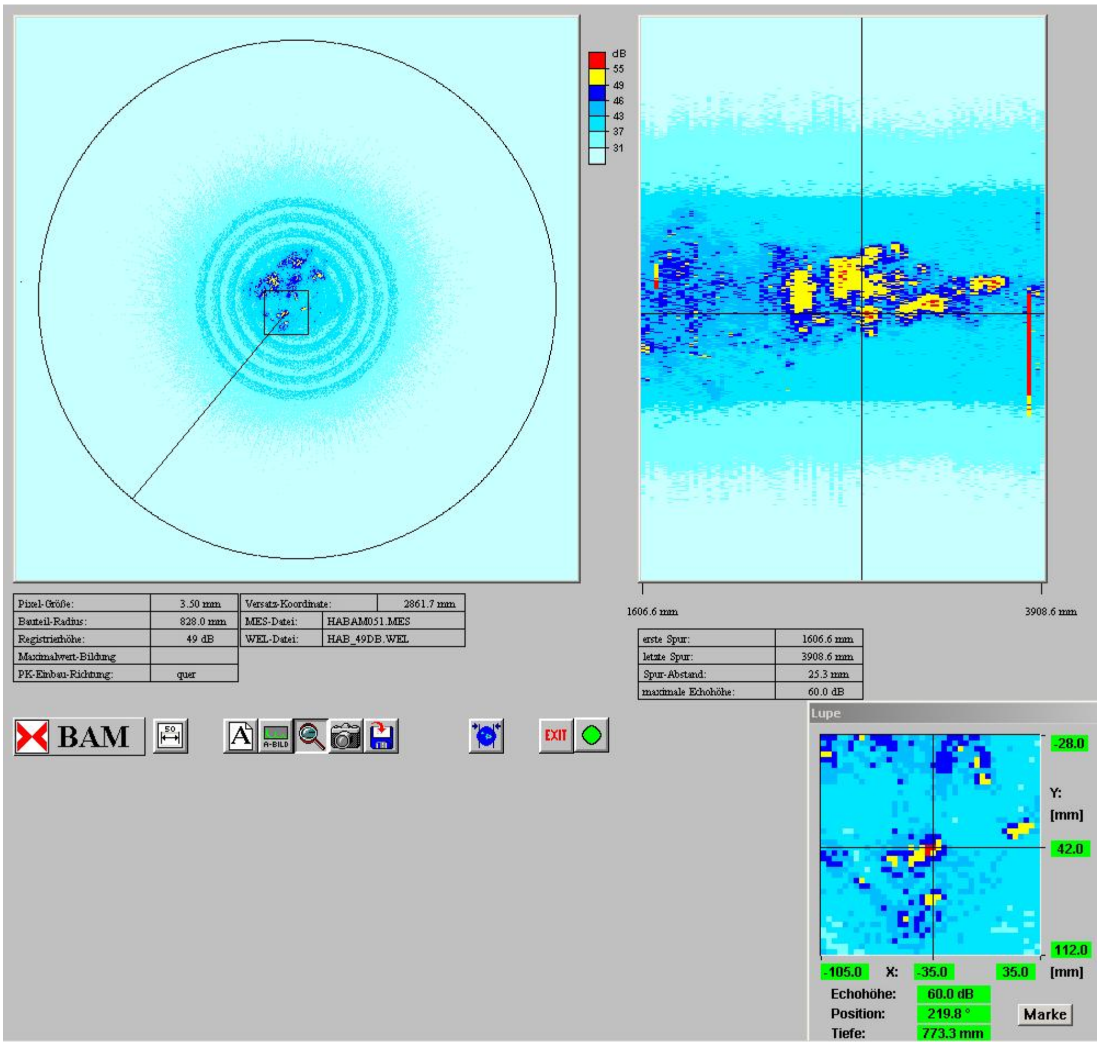
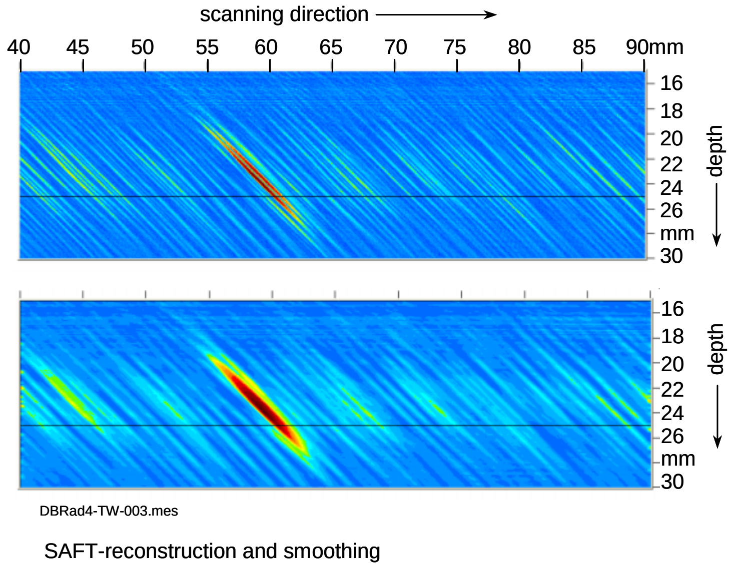


Fig. 2: Example of a tomogram reconstruction, side view of all reconstructed tomograms and lens function for zooming

3. Sizing of reflectors in a cladded test block using SAFT reconstruction

In a test block with a thickness of 25 mm 2 and 3 mm deep notches were inserted into the cladding. With 45° angle beam probe for shear and compressional waves the notch were detected in a half skip distance. Measured A-scans were recorded in RF mode. In the Fig. 3 and 4 representations of B-scan (upper Fig.) and SAFT reconstruction (lower Fig.) are given. Both measurement results show diffraction indications of the notch when using SAFT reconstruction. But only in case of compressional waves the diffraction indication may be clearly distinguished.



angle of incidence	45°
gain	53dB
measurement point distance	0.1 mm
voxel-size	0.06 mm
beam width	6.0°
beam resolution	0.1°
frequency	4 MHz
sound velocity	3255m/sec
pixel size	0.098 mm

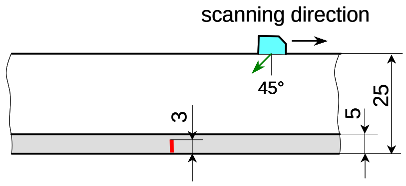
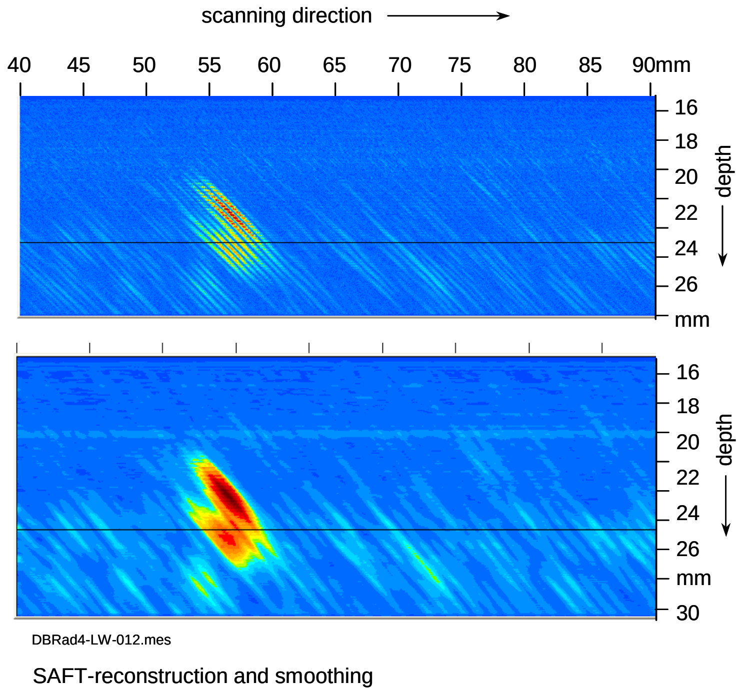


Fig. 3: B-scan- and SAFT reconstruction using shear waves



angle of incidence	45°
gain	49 dB
measurement point distance	0.1 mm
voxel-size	0.06 mm
beam width	6.0°
beam resolution	0.1°
frequency	4 MHz
sound velocity	5920 m/sec
pixel size	0.118 mm

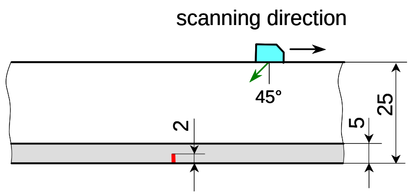


Fig. 4: B-scan- and SAFT reconstruction using compressional waves

4. Wheel set shaft inspection of carriages and waggons to detect transverse cracks

The measurement areas are covered with 4 phased array probes. Two probes which are arranged between wheel seat and the first brake disc seat (Pk1,Pk2) cover the wheel seat , emergency and blade area. Two other probes (Pk3, Pk4) cover the area around the brake disc seat. For wheel set shafts with a third brake disc the phased array probes (Pk3, Pk4) are additionally turned around by 180°, again positioned and inspect this area in a second test cycle.

Due to the fact that there are only a few , partly narrow wheel set segments accessible for coupling the measurement is done from fixed positions. Therefore the phased array probes must be equipped to cover a big scan area (25° to 75°). The scan area is covered by 1° steps.
The purpose of the inspection data evaluation is an easy and sure finding procedure.
For realizing this an imaging procedure is used. Images of the uncoiled cylindrical surface (UC - image) are produced which are generated from measurement data by reconstruction. Finding evaluation occurs after the end of the measurement by visual comparison between a reference image and the UC- image showing the finding to be evaluated.
The UC-image is a special form of the time-displacement (TD-)scan. Narrow stripes of the TD-scan representing the near surface area of the shaft are projected on the shaft surface and joined together to an overall picture.
Each TD-scan stripe is assigned to a value of the scan angle.
After calibration at a test shaft equipped with different reference reflectors the colour scale was chosen in such a way that findings which must be recorded may be immediately recognized by a red representation.

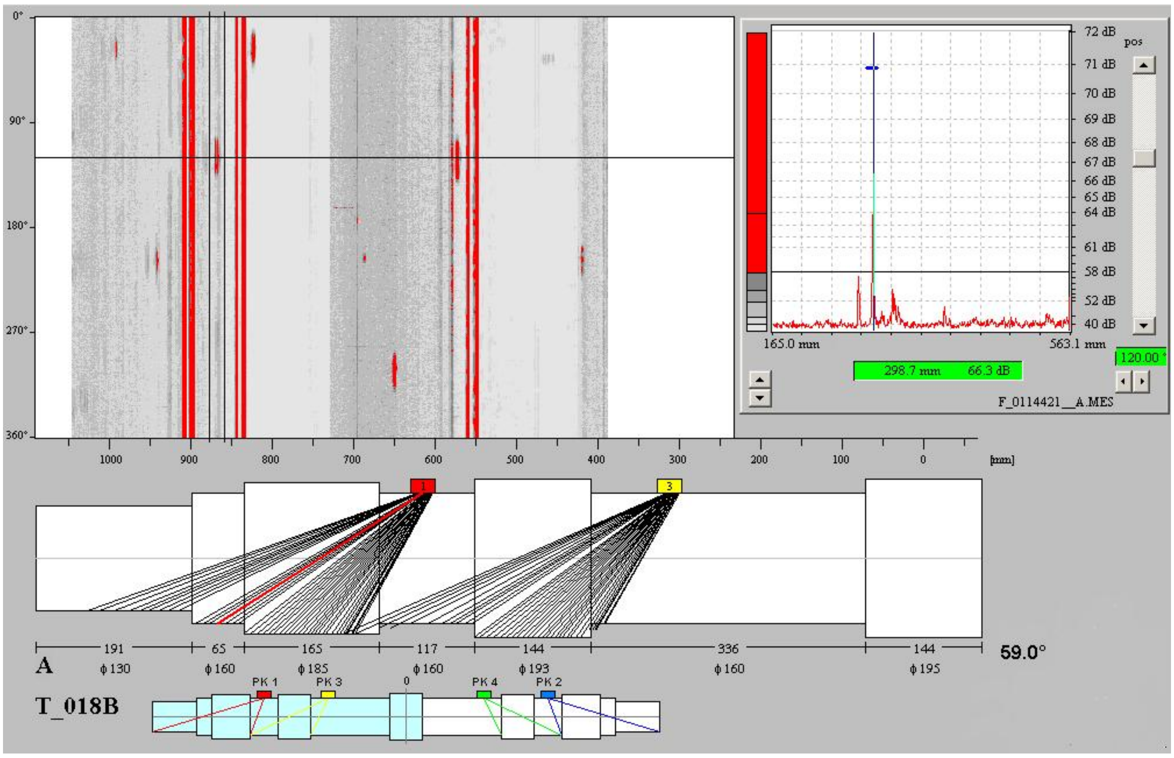


Fig. 5: UC-image representing the left side of a test shaft and indications of 8 reflectors

Fig.5 shows an UC-image representing the left side of a test shaft with a total of 8 reflectors each of them realized by 2 mm notches.
The geometrical indications of the shaft edges may be easily distinguished from the reflector indications because of the constant echo height in the whole UC-image covering a range of 360°.
Using scroll bars and keys each measured A-scan of the original measurement data may be selected and faded in the representation of the UC-image. The A-scan position is marked in the UC-image. The related amplitude and sound path of an echo indication may be quantitatively evaluated in the A-scan. The near surface inspection range of the sound path may be identified by a marker.

5. V-arangement with phased array probes for testing of ICE wheel discs

Sound beams of two phased array probes in tandem arrangement are swivelled in a defined section of beam angles. Coupling surface is the wheel tread. The beam angle changes occur for transmitter and receiver in the same way. So it is possible to detect tangential oriented flaws in different deep testing areas of the wheel disc. Each inspected area is then reconstructed in the echo tomogram in dependence of each used angle of incidence.

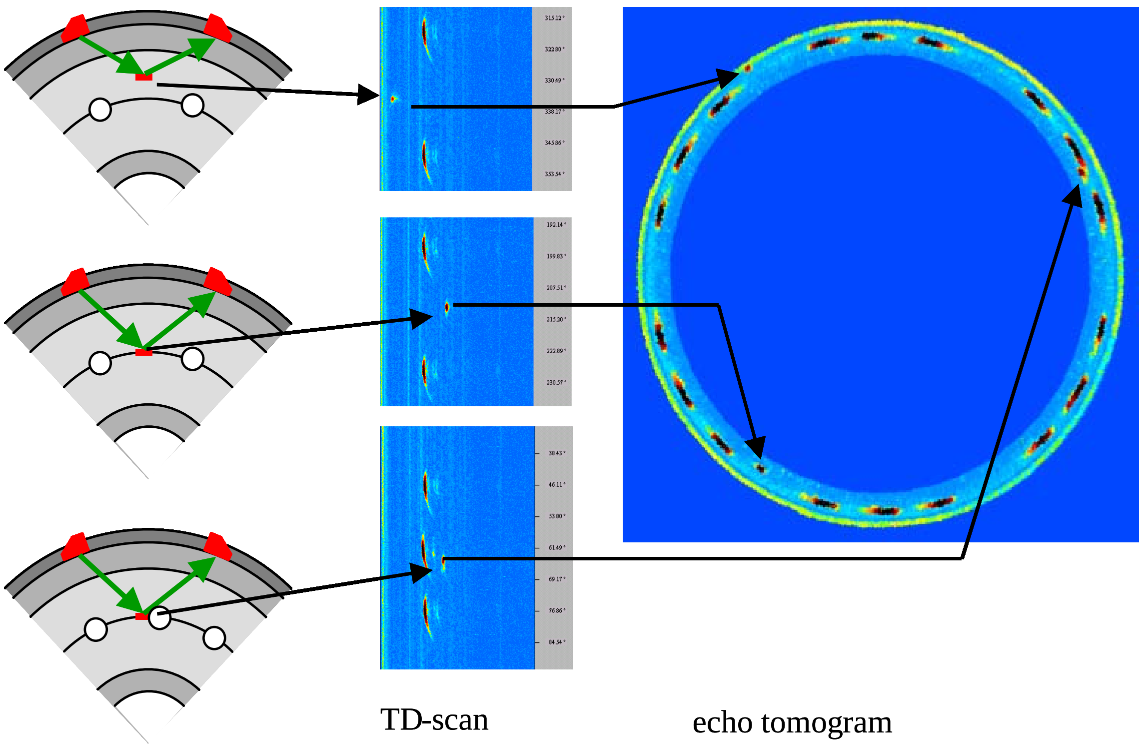


Fig. 6: Steps of echo tomogram reconstruction for transmitter and receiver probes in V-arrangement

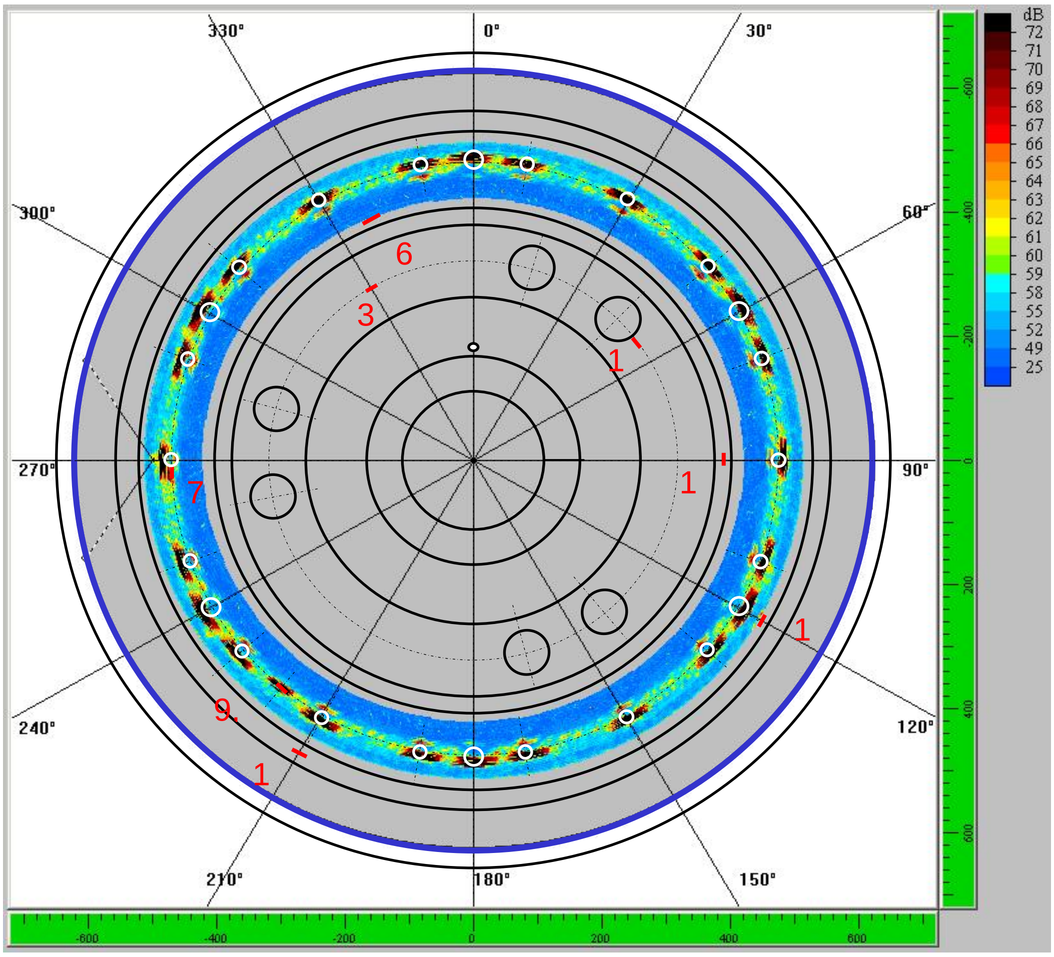


Fig.7: An echo tomogram as measurement result when using phased array probes in V-arrangement at an ICE wheel disc

Fig. 7 shows a part of the measurement area at an ICE wheel disc. Geometrical indications and indications of artificially inserted reflectors are marked in addition. In the represented testing area two 2 mm and 4 mm deep test reflectors are detected. With faded in cursors the V-arrangement position for each registered A-scan may be recognized as well as the related A-scan (Fig.8).

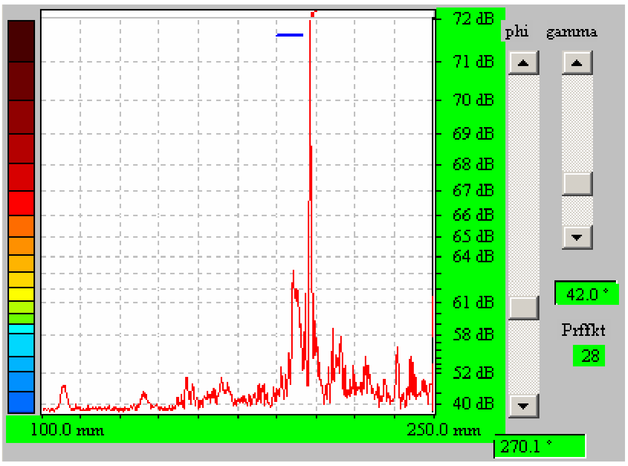


Fig. 8: A-scan representation of the marked V-arrangement in Fig.7.

The blue marked sound path area in Fig.7 shows the sound path region in the A-scan of Fig.8.

6. Summary

The visualization of the ultrasonic testing data offers to inspection personal the possibility to evaluate and to size an indication with signal amplitudes above the recording level..
In the automated ultrasonic testing the demand for immediate evaluation of an inspection result gets more and more urgent emphasis as it was shown in the example of wheel set shaft inspection installed to select defective pieces.
Other visualized representations as for example C-scans of welds, tomograms of nozzle edges or TD-scan representations of reactor pressure vessel's lid or bottom field have been realized by us.
The visualization of ultrasonic testing data may be geometrically expanded by registration of geometrical dimensions of components to be inspected. However there must exist as precondition a precise position related description of all ultrasonic measurement data. (index-point, direction of incidence, resolution, sound path region)

References

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