ALKO, A Step towards a Fast and Realistic Flaw Description in ISI

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ABSTRACT

Advanced imaging UT techniques show the potential for realistic sizing but usually require large sets of raw data. A new approach for UT systems, the ALOK technique, was introduced which uses data compression methods in order to enable advanced defect detection and sizing capabilities on the basis of practicable amounts of raw data, especially in the case of large-scale components. The basic principles of ALOK are described and the techniques for detection and sizing of indications are demonstrated.

1 THE NDT CONCEPT

The safety concept for the exclusion of failure of the primary components of nuclear power plants includes preservice and inservice inspections as a key element. Ultrasonic (UT) inspection plays a major role within this concept. According to the German nuclear engineering code (the KTA safety standards), inspection has to take place every 4 years using the tandem technique for the inner-volume zones of thick-walled components. The simultaneous application of different angles of incidence is required. The sensitivity of the inspection is based on a calibration at a 3 mm flat-bottom hole on a noncladded calibration block. To meet these requirements special equipment and techniques have been developed such as optimized probes, multiple-channel ultrasonic UT systems and special manipulators for remote positioning and scanning.

More than 15 years' field experience in the appliaction of inservice inspection techniques in German nuclear power plants is characterized by the following:

- large volumes to be inspected,
- few flaw indications to be evaluated and traced back, using sensitive detection thresholds,
- geometrical and spurious indications to be explained and excluded, which requires differentiation from flaw indications.

If an indication is detected, the safety and availability of a component can be evaluated on the basis of information about defects, loads and material properties using fracture mechanical calculations. The indications found by nondestructive test methods have to be transformed into real defect sizes (G. Batholome´et al., 1988). The crack present or to be postulated shall be so small that it only grows to a negligible extent as a result of all acting loads during the

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intended lifetime and/or inspection period of the component. For this safe-life situation primary the crack depth is of importance.

If it can be demonstrated that the length of the through-wall crack, after penetrating the ligament in multiples of the specified load collectives (beyond design situation), is smaller than the critical through-wall crack length, then only a leak before break can occur (see fig. 1). This leak-before-break behaviour which is applied to pipes is a fail-safe situation. The assumed through-wall crack grows very slowly and can be reliably detected by means of leak detection systems (G. Bartholome´et al., 1991) before the critical through-wall crack length is reached. To ensure this fail-safe behaviour the detection of crack length is of primary importance.

A realistic description of the reflector is required in order to avoid conservative overestimations using the safe-life or the leak-before-break philosophy. This and the above mentioned boundary conditions led to the following goals for the development of a new inspection system:

- For the few indications expected, the full information of the UT signals is required.
- All other data should be suppressed by an intelligent precompression technique.
- Based on the reliability of the precompression algorithm it should be possible to store precompressed data only.
- The system should be sensitive to any changes in defect sizes between two inspections in order to trace flaw growth reliably.
- A full analysis of indications including reconstruction of defects should be possible on the basis of standard inspection data.

Advanced imaging UT techniques show the potential for realistic sizing but up to now, mainly because of their requirement for large sets of raw data, they are expert tools and can only be applied as additional analysis techniques. A new approach for UT systems, the ALOK technique, was introduced in order to combine defect detection and analysis capabilities in one instrument. Its principal objective is to characterize an indication by its time-of-flight analysis rather than by its reflected amplitudes. This is possible because the set of raw data is reduced before storage by an on-line filter based on simple feature analysis techniques.

2 PRINCIPLES OF THE ALOK INSPECTION TECHNIQUE

The development of ALOK at IzfP was mainly supported by the German Ministry for Research and Development within the reactor safety program (Fischer and Heumüller 1990; Barbian et al 1981; Grohs et al 1981; Barbian et al 1985).Fig. 2 illustrates the ALOK approach to selecting the physical content from the high frequency information of each A-scan received. Conventional systems operate with preset time gates and identify the maximum peak and the corresponding time-of-flight value, which means one amplitude per time gate. ALOK is free of time gates and acquires the full A-scan information. After analog/digital (A/D) conversion, all maximum half wave peaks in every A-scan are further processed. In order to select only the relevant signals, the so-called i, k algorithm is used for precompression. It takes into account the response function of the probe to a single reflector which is a characteristic parameter of the individual transducer. Within the A-scan a local maximum with physical meaning is identified by a rise time of i half wave peaks and a decay time of k half wave peaks. Only the amplitude and the time of flight of the local maximum is further processed. Combined with the corresponding actual coordinates of the probe, amplitude/time-of-flight/locus curves can be generated. They are the basis for further data processing and evaluation. Thus a powerful data reduction by about a factor of 100 compared to the original A-scan data is achieved without losing relevant information.

3 ALOK EQUIPMENT AND DATA EVALUATION

Reactor pressure vessel inspections require simultaneous application of probe systems consisting of up to 12 single probes. The ALOK 3 version is equipped for the operation of 16 transmitters and 32 receivers. Between the analog front end and the data acquisition computer a distance of up to 300 m is possible. The data conversion rate is 50 MHz at a dynamic range of 80 dB. The scanning speed ranges up to 100 mm/sec with one sample per mm. Using a fast peak detector and the data precompression by the i, k algorithm mentioned above, up to 127 amplitude/time-of-flight values per transmitter pulse can be processed. The data are stored on optical discs (2 GByte) for further evaluation.

The inspection results are displayed in a comprehensive, clear presentation. The standard is a combination of 3 projection images representing a selectable part of the inspected volume. One top view (C scan) is combined with 2 side views (B and D scans). The scale of colors corresponds to the recording thresholds. When indications are detected, a zoomed projection allows the inspector to obtain, by using a cursor, detailed on-screen information e.g. the extension of the reflector. The standard representation of the results is complemented by additional features for further analysis. Useful information is provided by amplitude versus coordinate (AOK) and time of flight versus coordinate (LOK) representations. Spurious echoes can be clearly recognized using these representations. The comparison of LOKs of different inspections is a precise and sensitive method particularly for detection of changes in flaw size.

4 VERIFICATION AND PERFORMANCE TESTS

On account of the important role played by inservice inspections in the nuclear safety concept, verification of new inspection systems is necessary in order to ensure their reliability. The large-scale vessel mock-up located at the MPA-Stuttgart is well suited to this task because it represents the present status concerning geometries, materials and defects. ID nozzle inspection using the central mast manipulator was chosen. The measurements were taken in close cooperation with MPA-Stuttgart.

The nozzle geometry resembles exactly the reactor coolant inlet nozzle of the Siemens PWR of the so-called Konvoi type. According to the KTA safety standard, the volume of the nozzle-to-vessel weld was tested including the adjacent base material and the nozzle inner corner. The system was designed to detect and analyse axial und transversal flaws. The choice of transducers was identical with the standard ISI inspection system.

Evaluation of the inspection results is still in progress but a first review of the data did not show evidence that indication of any of the artificial flaws was missing.

5 INSPECTION OF AUSTENITIC MATERIALS

The ALOK technique is well suited to the inspection of a ustenitic materials, especially if large numbers of transducers are required in order to achieve short inspection times. The i, k-algorithm allows for sensitive recording thresholds, which means that reflector amplitudes in the range of the grain noise can be recored and made visible by geometry related projection views or reconstructions.

The first application was the development of an ISI inspection system for circumferential weldings of CRD housings. The system, now ready for the first field application, was tested using a one-to-one mock-up with EDM notches. Fig. 3 shows indications of axial OD notches. Data of 0.5, 1 and 1.5 skip distance of two transducers transmitting in opposite directions are overlayed. Thus a high redundancy of information is achieved and smal indications are visualized clearly.

6 FIELD EXPERIENCE

The ALOK system was introduced to the field in '87 for preservice inspection and has been used since '89 for inservice inspection. The technique, now qualified by German authorities and their inspectors, proved to have remarkable advantages with respect to a general improvement of the inspection, reduction of documentation and simplification of data evaluation. It was possible in 1989 to run at least two ALOK inspections simultaneously. In the meantime the capacity has been further increased in order to handle typical peak load situations, which sometimes arise due to the accumulation of planned outages at mid-year. The experience accumulated so far has confirmed the expectations regarding the system's efficient performance and the quality of the results.

7 OUTLOOK

Increasing experience will be accompanied by continuous research and development efforts. This implies the following tasks and goals:

- continuation and detailed evaluation of verification at the MPA large scale vessel,
- further enhancement of the evaluation algorithms including tomographic or quasi-SAFT reconstructions and 3D visualization tools (Langenberg et al., 1989).

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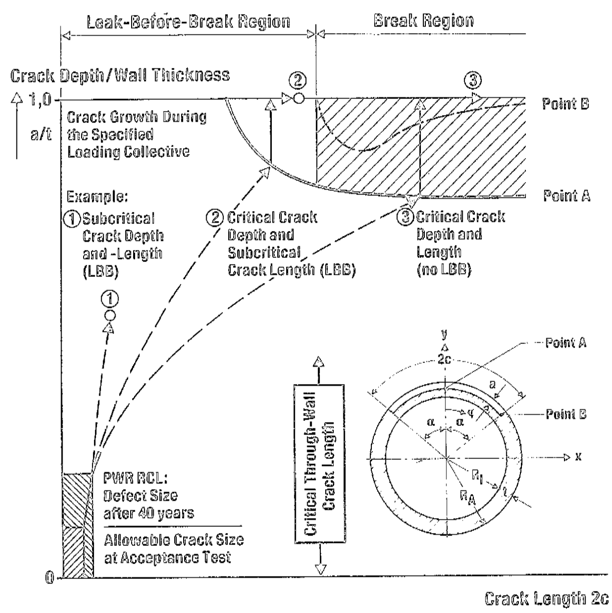

Fig. 1: Leak-Before-Break Diagram (Schematic)

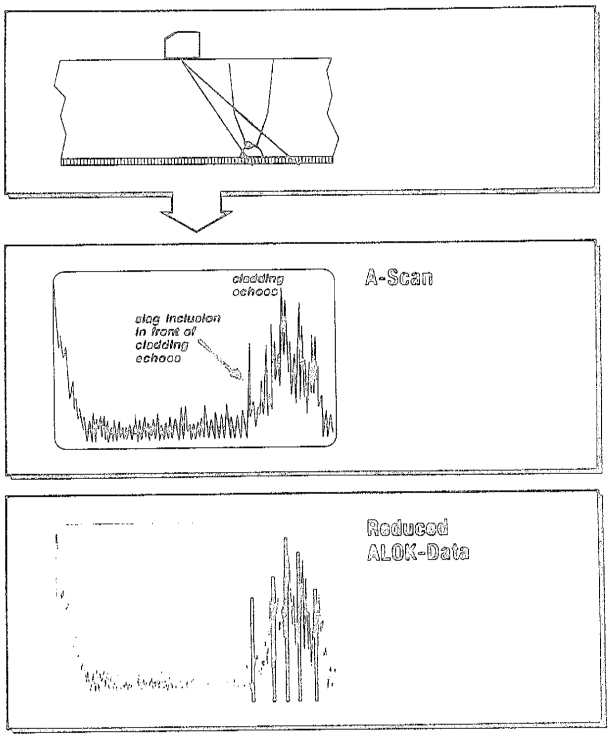

Fig. 2: Indication in Front of Cladding Echoes

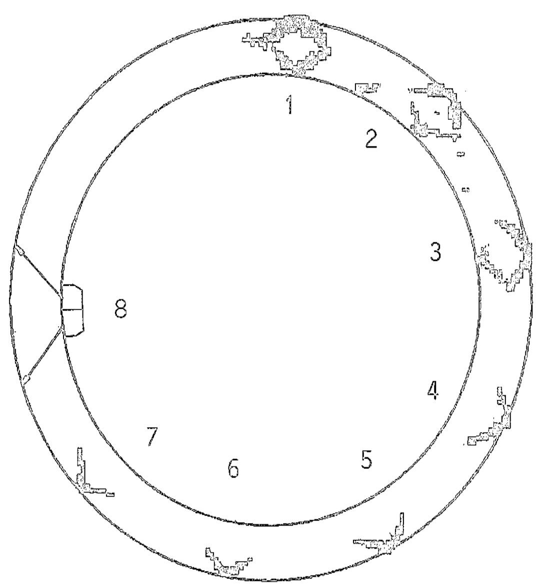

Fig. 3: Reconstruction of axial OD-notches with depths between 0,5 mm and 9 mm (1-7) using an angle of incidence of ± 45° (8)