EXPERIENCE GAINED FROM MECHANIZED ULTRASONIC TESTING

Jiri CERMAK, Vincent CHARDOME, Eric CRUYSWEEGS, Michel DELAIDE, Manuel PLATEAU, Francis LEEMANS, AIB-VINÇOTTE INTERNATIONAL, Brussels, Belgium.

ABSTRACT

Since several decades the mechanized ultrasonic testing (UT) is applied in nuclear power industry and plants. The apparition of computer technology and its fast performance evolution and size reduction has allowed to build portable and light phased array or multi-channel UT equipment for, among other things, ultrasonic examination in tight areas of piping in nuclear power plants. The requirements of mandatory performance demonstration or requested qualification according to ENIQ rules conducted in many cases to the application of data recorded examination. Moreover the UT examination of welds in high radiation dose rate areas requires fully mechanized methods.

ALARA approach, duration of data collection, traceability of results, performances in detection rate, sizing capability and related costs will be reported in this paper from several years experience in mechanized and manual UT examination.

INTRODUCTION

The mechanized, also called some times, automated or remote ultrasonic testing is applied since several decades in the industry. We understand here as mechanized or automated UT examination (AUT) when digitised signals, positions, time of flight and all set-up parameters are recorded, stored and displayed in order to reconstruct A scans and 2D or 3D image of the sample under testing. The AUT can be other motorised or moved manually.

The construction of nuclear power plants and pipe lines contributed to a large development of the mechanized UT testing. The requirements from the performance demonstration (demonstrate the crack can be potentially found) conducted in many cases to use the AUT.
Special attention is brought to materials heaving the reputation to be hardly UT examined such as stainless steel, dissimilar metal welds, stainless steel castings and welds. Together with the capability to build dedicated UT search units and manipulators or robots, the efficiency of the AUT leads to 100 % of detection and enhanced sizing capability. The latest development in the phased array technology improves even more the efficiency of the AUT.

Moreover the recorded data can be reviewed, discussed, filtered for more detailed analysis. In the nuclear environment, where high radiation dose rate is present, the AUT offers acceptable solutions for the component quality assessment.

MECHANISED UT ON PIPING IN NUCLEAR POWER PLANTS

FROM: (in place of “IF”, from Rudyard Kipling…)

From pencil	to computer,
From PDP, Commodore, Tektronix	to PC,
From PCXT AT	to Dual processor QUAD,
From DOS	to Windows,
From Kbytes	to Gbytes,
From paper design	to CAD,
From quartz	to piezo-composite,
From single	to phased array,
From medical imaging	to phased array 3D representation of welds,

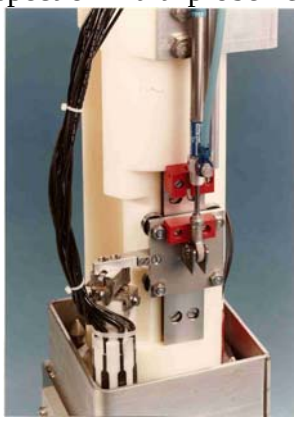
Then fast and reliable UT!

When paper design was still in use, manipulators for automated UT examinations were deigned, manufactured and applied in the industry. Thus the mechanized UT examination was performed in reactor vessels, for stainless steel piping welds and for some special applications as the impact weld for heat exchangers. When the stainless steel design of welds in the nuclear industry appeared, a big effort was made by Vinçotte to build dedicated low frequency UT search units. The combination of the mechanised UT and these search units conducted to many efficient qualification in terms of detection and sizing of flaws. Things became easier with the apparition of personal computers, powerful capability of calculation and CAD.

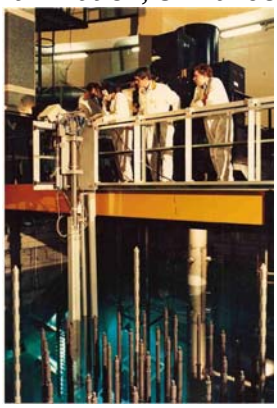
Examples of AUT examinations

The flexure examination, components in reactor vessel (1983):

Inspection multi-probe head

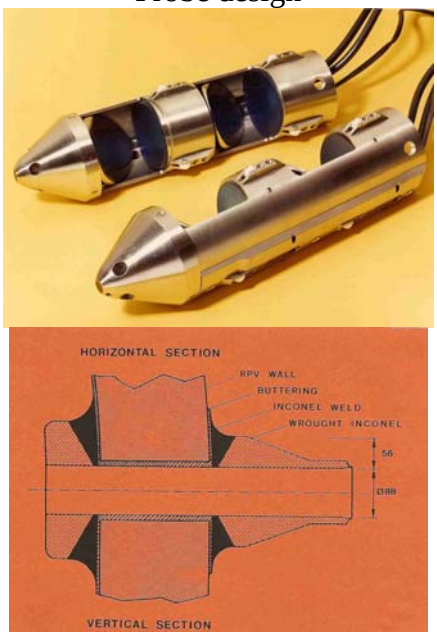


Field examination, 8 m under water

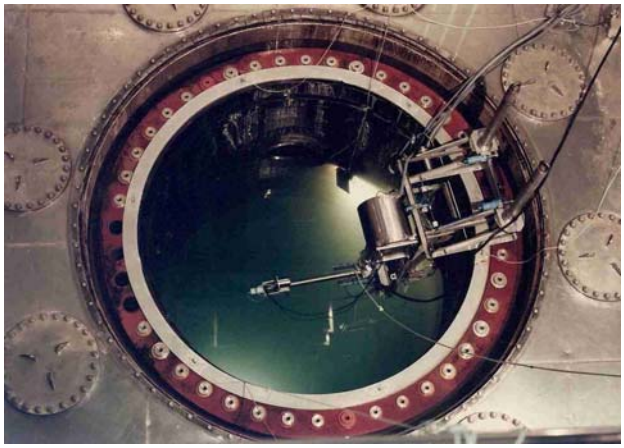


The examination of safety injection nozzles, special design entering directly in the reactor vessel (1985):

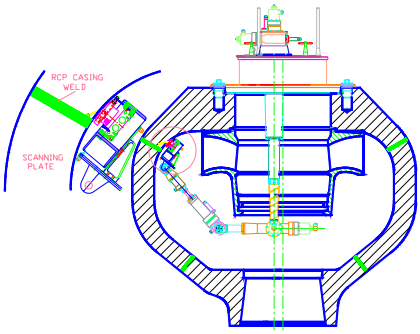
Probe design

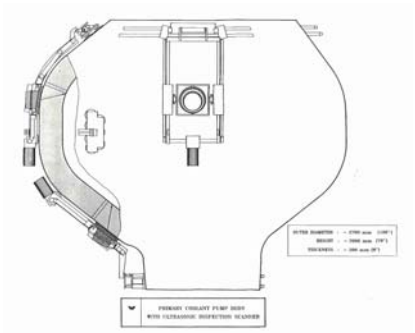


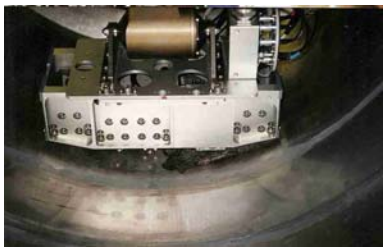
Site examination



The examination of primary pumps electro slag welds from outside and inside was performed in 1988 until 1996:







The examination of dissimilar metal welds of pressurizer was qualified in 1999 for 4 to 14 inches diameters. Further qualifications were successfully accomplished for homogenous welds from 6 to 36 inches diameters piping. Moreover primary piping of the PWR Nuclear power plants were inspected. The piping in BWR was also examined using the same UT system. Furthermore, the system was also qualified for the examination of retaining rings of alternators.

Description of the AUT system (used since 2000)

The examination is performed using ultrasonic examination techniques, which are based upon the implementation of contact probes from the external surface.

The complete UT system consists of three major parts:

- A scanning mechanism: namely the PIMMS 2000, a dedicated 2-axis scanner for the examination of austenitic piping welds from the external surface; this device carries the ultrasonic probes, which are mounted together in so called "probe frames"; the probe movement is motorized and encoded according to two axes, across and along the weld. The PIMMS 2000 is especially designed for piping in nuclear power plants. The benefits of its improved design are the reduced weight, the possibility to use it on conical and pipe-to-elbow configurations, the use of encoders and powerful DC motors for accurate positioning of 10kg of probes.

- An UT data acquisition system: the acquisition of the UT data is performed using:
  - the µTomoscan system, a multi-channel system with internal 4-channel pulser/receiver.
  - the Omniscan system, a UT phased-array system.

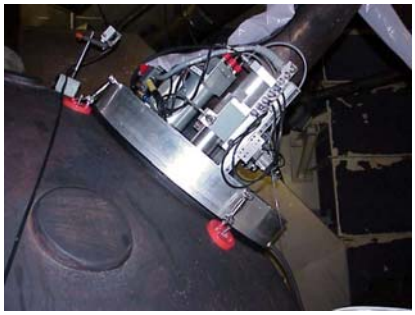
  Both systems allows for digital recording and storage of the ultrasonic data.
  A MCDU-02 servo motor driver is linked to the UT equipment, which controls the movements of the scanning mechanism.

- An UT data analysis system: the analysis of the UT data is done on a Personal Computer equipped with the earlier Tomoluis, now Tomoview or Ultravision software. The transfer of the data is done by means of CD, DVD, hard disks or memory stick.

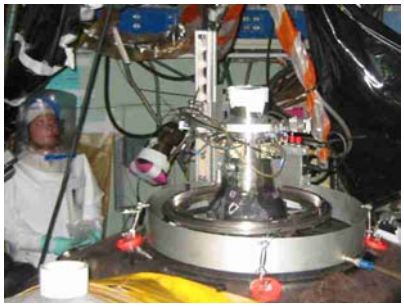
For communication purposes, a headphone connection is provided between the acquisition system and the scanning mechanism. To limit human presence near to the welds (Radiation - ALARA), the movements of the scanning mechanism are monitored by a closed video circuit.

Examples of examination of the pressuriser 4, 6 and 14 inches DM welds:

6 inch DM weld



4 inch DM weld



14 inch DM weld

Examples of examination of the piping welds:

Steam generator outlet welds (DM and narrow gap)

6 inch pipe, homogeneous stainless steel weld

BWR, re-circulation piping weld

PERFORMANCES, RESULTS FROM QUALIFICATION MECHANIZED VERSUS MANUAL PROCEDURES

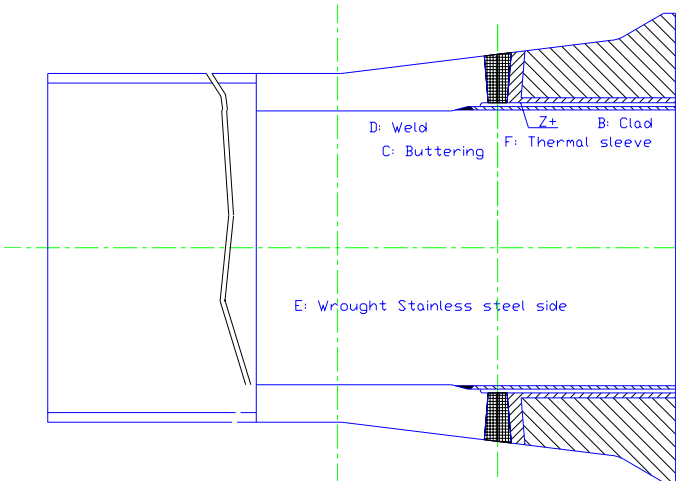
The performances of the mechanized UT examination are recognized to be better then manual examination. One example is given here under. Many others could be given from large experience.

The qualification for the examination of dissimilar metal weld of the surge line of pressurizer was carried for manual examination, as this was requested by the owner. All necessary provisions were made for the possible success of the qualification. The qualification was carried as a blind test.

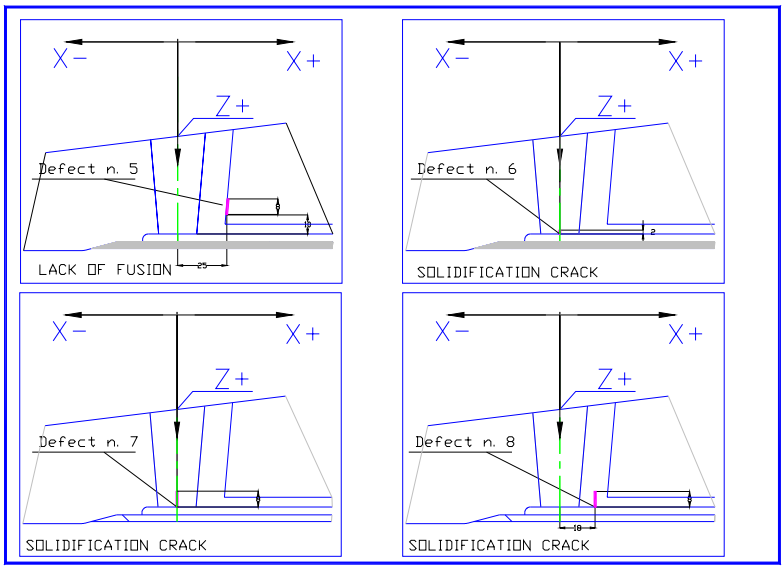
One full size and representative mock-up was provided. The mock-up is a 14 inches DM weld 50 mm thick in the centre of the DM weld.

Several cracks were introduced in the weld, most of them far surface breaking, having through wall size (TWS) 2 to 8 mm. The cracks are located in the centre of the weld and in the centre of the buttering. Two subsurface lack of fusion are on each side of the chamfer. More over five transverse flaws are present. Two of them are cracks (4 and 8 TWS) and the others are EDM notches (1, 2 and 4 mm TWS).

DM weld 14 inches mock-up:



Example of flaws:



Procedure was written according tests done for detection and sizing. Some dedicated search TRL probes were designed and manufactured. The tests done by the specimen designers concluded in the very good performances of the TRL probes in terms of detection and sizing. 100 % of the flaws could be detected and sized. Lots of geometric and metallurgic signals are present together with the signals coming from the flaws, the challenge is thus to make the difference.

Five UT operators, UT LII were chosen to perform the personnel blind test qualification. The accent was set on a maximum detection rate. No limits were put for the UT examination duration.

The results can be summarised as follows:

- The detection rate is from 50 to 75 % of flaws parallel to the weld;
- The detection rate is 0 for flaws transverse to the weld;
- Lots of fall calls were made;
- The RMS for TWS sizing of detected flaws is 5.9 mm.

The results were stated as unsatisfactory.

Moreover the duration of the UT examination for detection was 8 to 12 hours and 4 to 8 hours for sizing. The dose rate at these welds on field is around 8 mSv/h.

The alternative by means of automated UT examination was suggested to the owner. The procedure was adapted for the automated UT equipment. The same TRL probes were used for the procedure and tests. An UT LII operator performed the data acquisition. This operator did not participate in the blind test qualification. Three UT LII operators underwent the blind test for personnel qualification.

The results can be summarised as follows:

- The detection rate is 100 % of flaws parallel to the weld;
- The detection rate is 100 % for flaws transverse to the weld;
- No fall calls were made;
- The RMS for TWS sizing of detected flaws is 1.7 to 3.1 mm depending on operator.

The results were stated as satisfactory and the automated procedure validated.

Moreover the duration for the manipulator set-up was 20 minutes and 10 minutes for the manipulator removal. Experience and training made these times shorter.

Since this qualification, the procedure was extended to 4 and 6 inches DM weld of the pressurizer. Moreover tests on the Ringhals [1] primary test specimen B1 (cast to centrifugally cast stainless steel primary weld 60 mm thick, containing mechanical fatigue, solidification and cluster cracks, lack of sidewall fusion) extended the qualification to primary loop welds using the ENIQ recommended practice for qualification and Technical Justification.

Since 2000 the Phased Array (PA) technology was introduced in the process of qualification and field applications [2]. Indeed the apparition of portable and high-performance PA equipment and PA probe development allowed the industrial reliable application at reasonable cost.

The multiple TRL probes were replaced by TRL PA modules, certainly more expensive per unit but less in number of necessary units.

Number of TRL probes for one procedure
(4” to 36 “ welds)

Equivalent units in PA version
(Removable wedges 4” to 36”)

Some others experiences showed that the AUT perform better then manual UT examination (MUT). Lots of flaws were detected by the AUT, could be assessed in terms of acceptance criteria. These detections were one of the bases of some correctives actions as the replacement of welds or the structural overlay repairs. Qualification was done for these new weld process by means of AUT.

Similar conclusions were made for the retaining rings UT examination. The AUT fulfils the requirements when the MUT could make it but in prohibitive time duration and only for detection.

CONCLUSIONS

Experience gained from nearly 30 automated or mechanized UT (AUT) examination was presented. Some considerations were done in comparison to manual UT examinations (MUT).

The AUT provides, especially when examining stainless steel, dissimilar metal and cast component welds, the following advantages in comparison to MUT:

- Enhanced performances in terms of probability of detection and sizing;
- Often the only way for satisfaction of requirements (appendix VIII of section XI of the ASME code);
- Traceability of results;
- Recording and storing of the data;
- Full coverage of the volume to be examined;
- Follow-up of successive examinations;
- Possible consulting of performance by NDE experts;
- Nuclear safety requirements, ALARA considerations (Time spent in high radiation areas);
- Relative cost to performance considerations.

REFERENCES

[1] Vattenfall Ringhals, Report nr 0788/96, “Results from Round Robin Test performed by Vattenfall Ringhals on cast stainless steel”.
[2] M. Delaide, Ph. Dumas, WCNDT Montreal 2004 “Application of Piezocomposite Twin, Side by Side, Phased Array UT Probes for the Inspection of Stainless Steel”