Enhanced Inspection of Tube to Tube-Sheet Welds in Heat Exchanger and JTFA for Defect Characterisation

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In this paper is presented a combined methodology to detect, position, size and characterize defects in tube to tube-sheet welds in HP Urea equipments. Geometrical reconstruction of ultrasonic scan do not always allow to characterize the defect as planar or volumetric.
A dedicated acquisition system has been built in order to enhance C-Scan, B-Scan and 3D defect reconstruction and add signal frequency contents information by using GABOR spectrogram analysis (Short Time Fourier Transform). Several samples have been manufactured by using the most used materials reproducing by welding the same material characteristics, FBH (Flat Bottom Holes) and SBH (Spherical Bottom Holes) of different sizes have been machined in order to simulate the closer to reality situation.
More than 300 artificial defects have been detected, sized and analyzed on tube of different sizes with different probes in order to find a common STFT feature extraction to be used in evaluation.

1. Introduction

UT inspection on GTAW tube to tube-sheet welds (see fig. 1) in HP Urea equipments is well established since few decades and the main purposes are:

- Verify the weld leg length and throat thickness (see fig. 2)
- Investigate the welds for typical defects (see fig. 3)

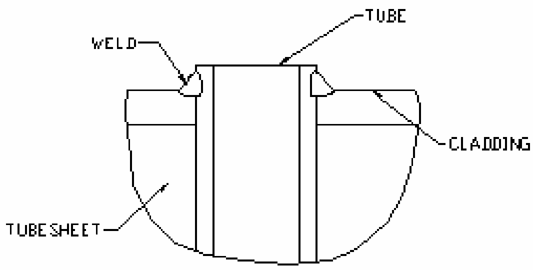

Fig. 1 Tube to tubesheet weld scheme

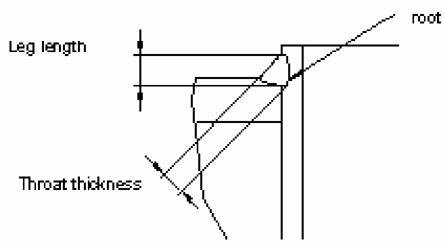

Fig. 2 Geometrical weld features

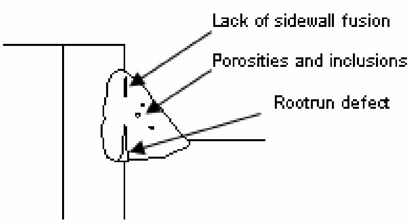

Fig. 3 Typical defects

Elongated discontinuities are to be considered as planar defects and can be recognized by means of geometrical defect UT response reconstruction, but in some cases there are defects whose shape is not enough to define with acceptable certainty its nature. The more frequent case occurs when improper tack welding procedure is adopted. In this case, defect characterization is very important both for defect severity and for weld process parameters adjustment.

Advanced signal processing better known as Gabor transform or STFT provides additional information which have been proven to be effective starting in 90's. The main objective of this study is to implement in a production environment the new tools originated by STFT. This means that the separation between planar and spherical reflectors has to be emphasized and simplified in order to allow UT operators to make reliable decisions in the shortest possible time.

2. Hiscan System description

In recent past, UT and Signal acquisition and processing boards development have improved significantly and are easier to be implemented. STFT algorithms are now available as standard for programming in National Instruments Labview platform and this has been chosen as the base for system development.

The system can be described as follows:

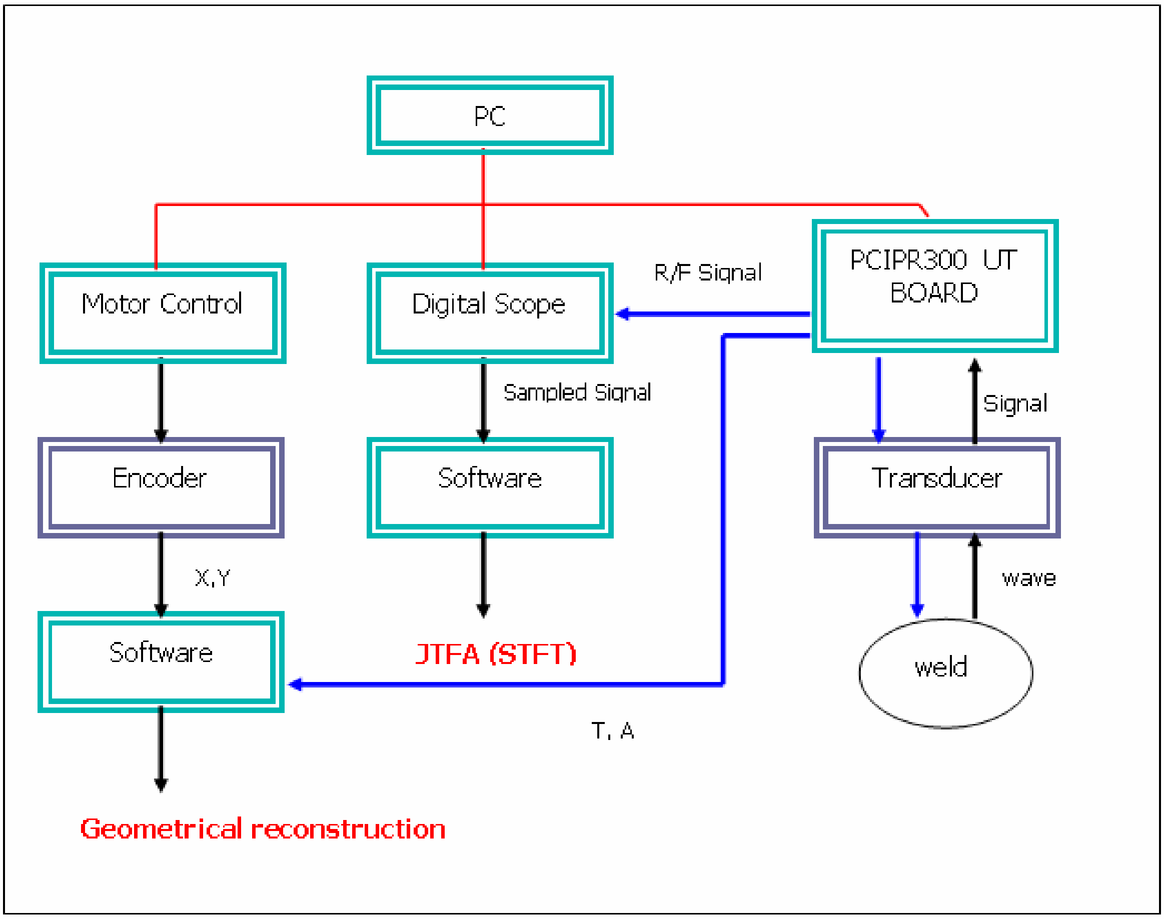

Fig. 4: Hiscan system flowchart

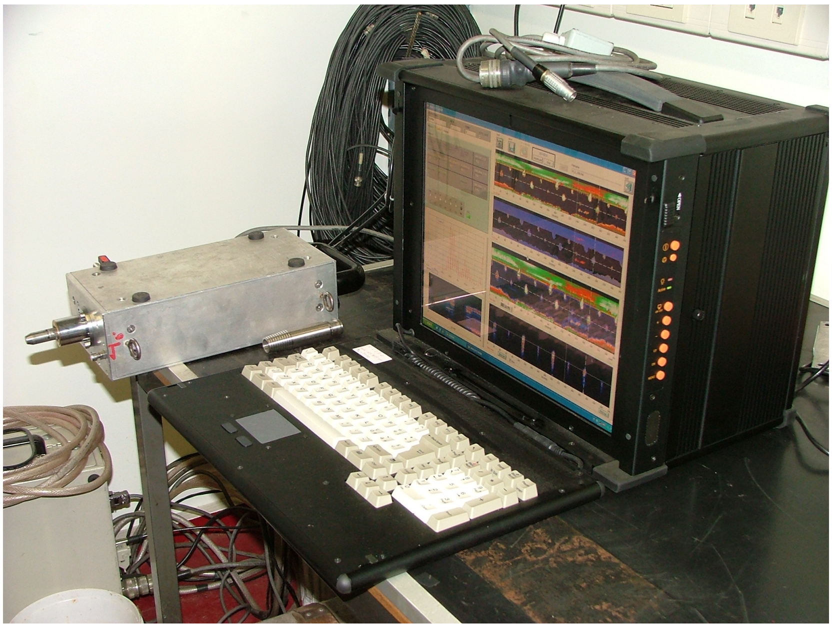

Fig. 5: Hiscan system with bore probe

3. Sample description

A total of more than 300 artificial defects have been analyzed having size from 0,8 mm to 3 mm (SBH and FBH), on 3 different tubes ID (14,5mm, 19mm and 22mm) and 3 different materials (Titanium, AISI 310 Mo Ln and Zirconium Zr702).

Fig. 6: Test sample

4. Scan description and geometrical reconstruction

In order to minimize scan time without information loss an helicoidal scan has been provided with adjustable index in order to guarantee 100% coverage of the weld volume and to ensure to record the reflector response at its maximum amplitude. The C-Scans are indexed so that the final image has no distortion.

5. Geometrical reconstruction analysis example

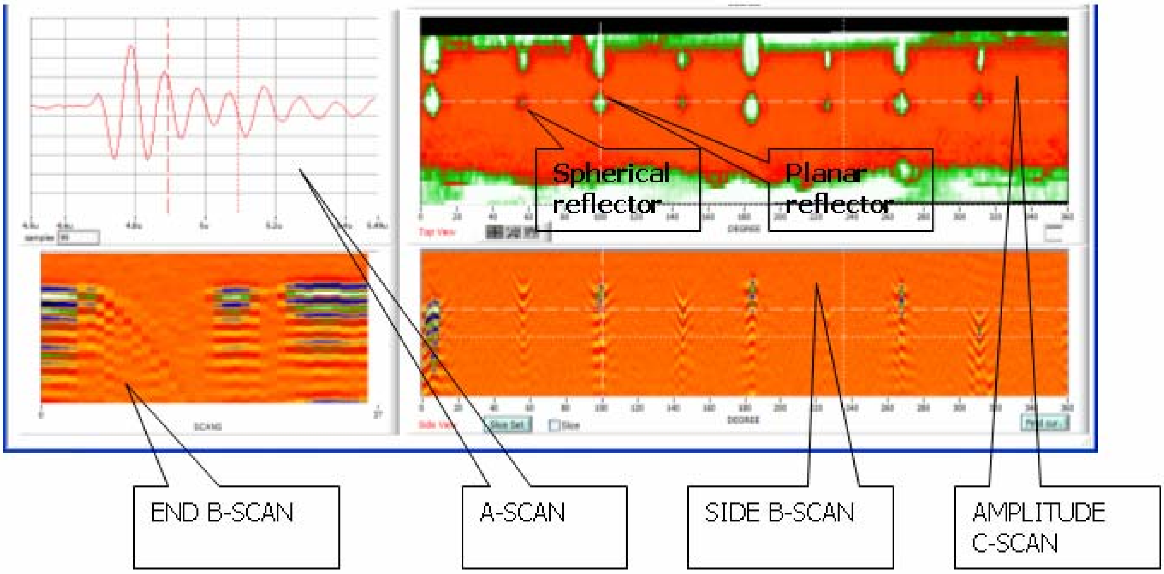

Fig. 7: Typical geometrical reconstruction

As evident on the C-Scan, the SBH looks smaller than the FBH, but it is not possible to state that they are not just smaller FBH, therefore additional analysis has to be performed in order to characterize the shape of the reflector.

6. Evaluation example

Titanium Sample, ID 19 mm.
Artificial reflectors: FBH 1, 2, 3 mm; SBH 1, 2 mm; natural porosity 0,45 mm

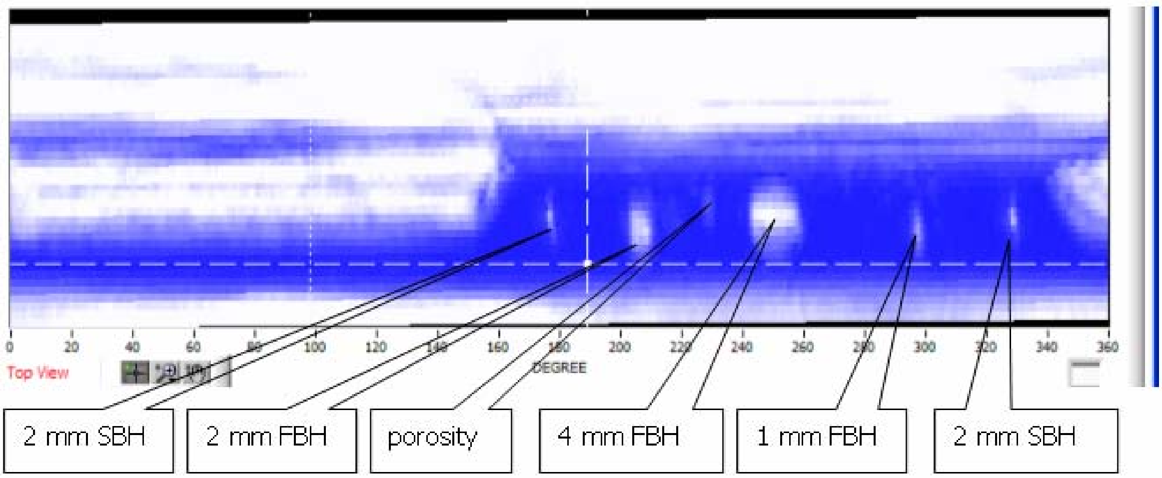

Fig. 8 : Amplitude top view

Once more, it is not possible to characterize the shape of the reflector. In addition, the 1mm FBH looks very similar to a 2 mm SBH.

STFT EVALUATION: FBH, SDH 2 mm and natural porosity

STFT comparison

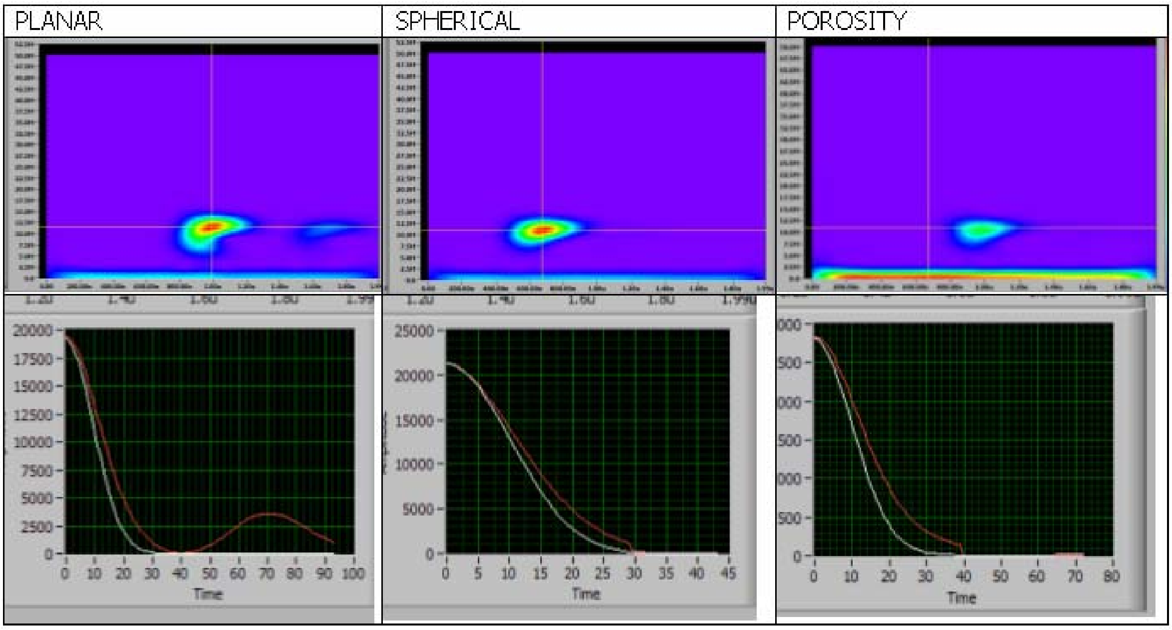

Fig. 9 : FBH (left), SBH (center), natural porosity (right)

This sample is giving the more complete comparison in the whole batch and has shown a very high repeatability over 5 consecutive scan. Very similar results were obtained with all the diameters with the three different probes used. Better results were obtained on titanium and Zirconium due to lower grain size compared to AISI 310 Mo LN.

7. Conclusion

It has been experimentally verified that the STFT analysis is capable to determine, with good repeatability and confidence, the difference between planar and spherical reflectors, when C-Scan and B-Scan presentations evaluation cannot fulfil this requirement. This tools has been implemented as an evaluation tools in a test production environment and the decision making process takes just few seconds, with no influence on the overall production.

Development of specific algorithms is in progress in order to obtain an automatic defect characterization and reduce operator's interpretation of results.

Further UT applications could be successfully addressed in order to cover the actual lack of information and increase the confidence of defect characterization.