VISION STERÉOSCOPIQUE DE SOUDURE À PARTIR DES TEMPS DE VOL ULTRASONORES EN PHASED ARRAY

STEREOSCOPIC VISION OF WELD BASED ON ToF PHASED ARRAY ULTRASONIC TESTING

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Résumé

Les techniques par ultrasons pour l'inspection de soudure se concentrent principalement sur la détection de défauts. L'utilisation et l'interprétation des temps de parcours ultrasonores peuvent délivrer des informations géométriques complémentaires. Cela permet, après analyse des données, de voir des imperfections internes et superficielles (ex : manque de pénétration, mesures de la qualité du premier passage). L'utilisation des techniques multi-éléments fournit les informations nécessaires mais l'interprétation des signaux peut être difficile pour un non-spécialiste. C'est pourquoi le travail présenté ici propose l'utilisation de la méthode de mesures ToF effectuée par divers éléments du phased array (capteur multi éléments) afin de construire une vision stéréoscopique de la section de soudure à travers, par exemple, la circonférence d'un tube. Les images peuvent ainsi être très intuitives pour un non spécialiste du domaine et ouvrent de nouvelles perspectives d'application du phased array.

Abstract

Ultrasonic weld inspection techniques mainly focus on flaw detection. The utilization and interpretation of the time of flight of the ultrasonic waves can provide additional information about the geometry of the flaw. After analysis of the data, this enables us to detect both internal and surface flaws (e.g. insufficient penetration, measurement of the quality of the first pass). Use of phased array techniques provides the necessary data but the signals may be difficult to interpret for a non-specialist. This is why the work presented here proposes use of the ToF method, based on measurements by the phased array elements in order to construct a stereoscopic vision of the weld cross-section through the circumference of a tube for example. The images produced can therefore be highly informative for a non-specialist in this area, and open up new perspectives for phased array applications.

INTRODUCTION

One interesting feature of the phased array ultrasonic testing is the use of many elements to fire and detect signals. Emission and detection can be controlled according with particular interests of detecting both internal and surface flows. On the other hand, high quality techniques (i.e., in the μm range) to detect surface characteristics as those based on laser are commercially available [1]. But light does not penetrate thick metal-bearing materials to assess, for example, wall thickness of a pipe or a weld seam. Ultrasonic testing (UT) is a well established approach to assess surface, interior and wall thickness properties of solid materials [2]. Despite the fact A-scans can be obtained, and B-scans and C-scans can be constructed and are very informative, a three dimensional representation of the investigated piece is indeed a very interesting approach [01]. Furthermore, the present paper reports the application of phased array UT to record wall thickness of weld seams and the generation of an artificial three dimensional representation using stereovision.

MATERIAL AND METHODS:

Phased Array Sensorhead

The phase array applied in this study has 32 aliened active elements, each of wwxyy mm.

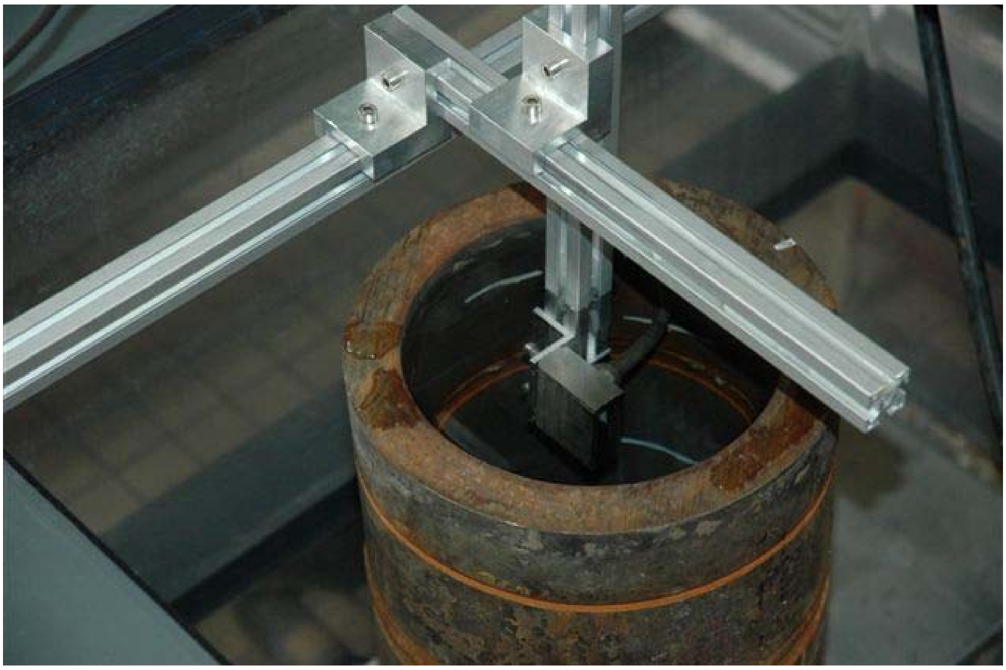

Figure 1. Experimental setup used to record phased array UT data on weld seam. The phased array sensorhead is fixed and the pipe filled with water turns clockwise. Installing the phased array outside will produce the same effect.

ToF calculation using Genetic Algorithms

There are different approaches to calculate the time of flight (ToF) of ultrasonic waves in A-scans [01]. It was decided to use genetic algorithms [06] and classical local search methods because of the capability of this optimization tool to be applied in an automated manner [De Souza, 99].

Basically, A-scans are obtained from the phased array probe. Interface and back wall echoes are least-squares fitted using Log-Normal curves. It was decided to use log-normal because its complexity will be challenging for the optimization routines and because it falls within the US signal by a simple eye-fit. Distance between two peaks is referred as the Time of Flight (ToF) spends by the ultrasonic wave to cross the layer (wall or weld). Figure 2 illustrates the fitting procedure in an A-Scan.

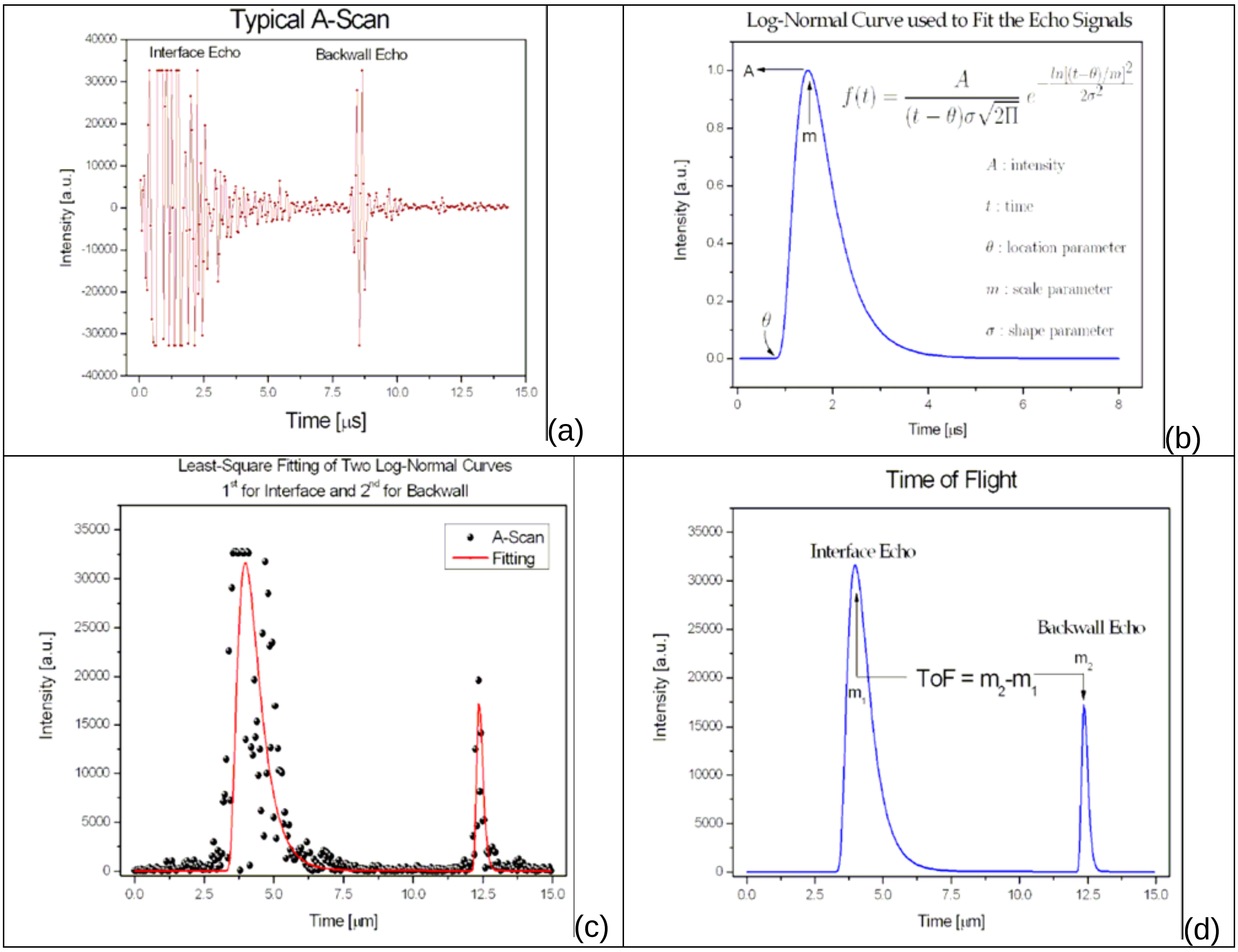

Figure 2. Topographical representation of the sections of 5x5 mm and 10x10 mm constructed for calibrating the measurements on layer thickness of the welds. (a) typical A-scan recorded for one element of the phased array; (b) log-normal curve used to least-square fit the absolute values of the A-scan; (c) typical least-square fitted A-scan and (d) ToF calculation from the peak position.

The relevant information to be assessed from phased array data is the time of flight (ToF). Time of ultrasonic signal flight is necessary to obtain the wall thickness (WT) or the layer thickness (LT) of the weld. Basically, time of flight corresponds to the time of travel of the sound in the media provides the thickness.

Topological Representation:

From a matrix containing the ToF of each element of the phased array for a given angular position it is possible to display topographical representation of the irradiated section. The software ORIGIN v. 7 is used to plot this data.

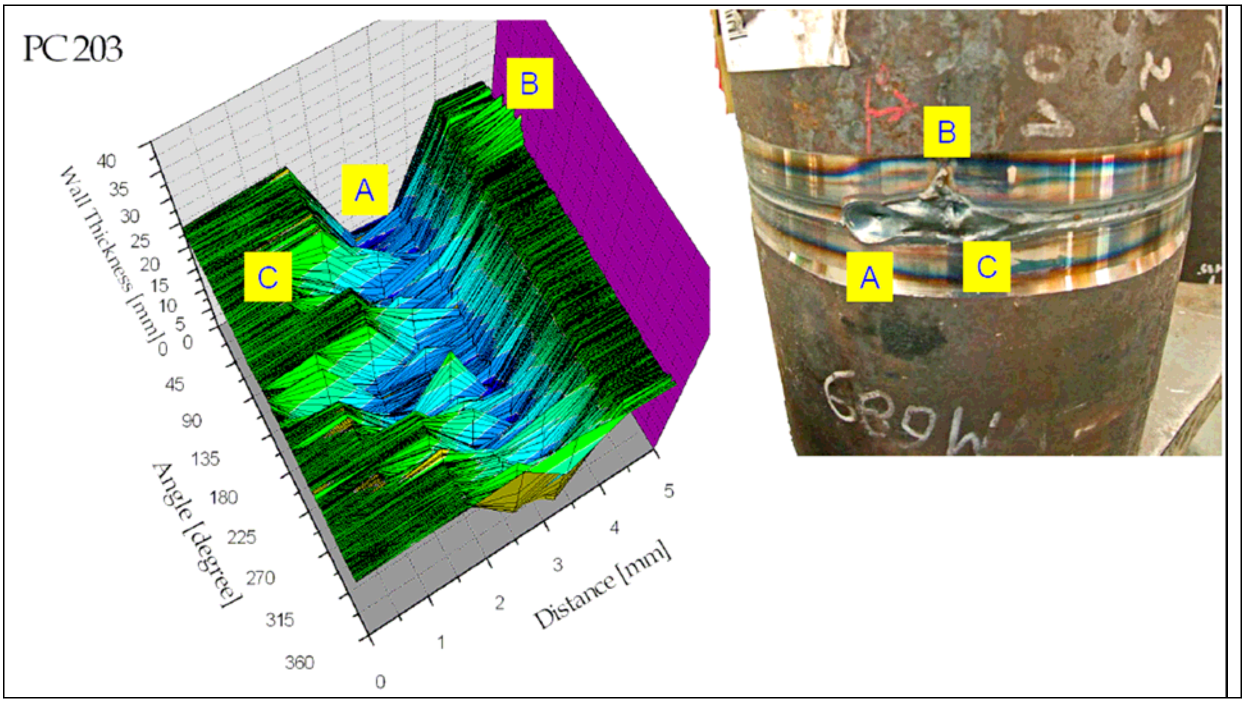

Figure 3. Typical result obtained with a sample with artificial defects.

Calibration:

Two annular sections were created to calibrate the measurements on weld layers. One has 5 mm x 5 mm and the other one 10 mm x 10 mm. These sections, as well as the weldings, are smaller than the phased array sensorhead. This means the section and its surroundings will be irradiated by the ultrasonic waves (see scheme PA and weld). They were measured from inside and outside the pipe. So far, better results were obtained from inside the pipe (see Fig. 1). Results are depicted in Figure 4 and listed in Table 1. The necessity for additional calibration values will be evaluated after the analysis of results obtained with further experimental Improvements.

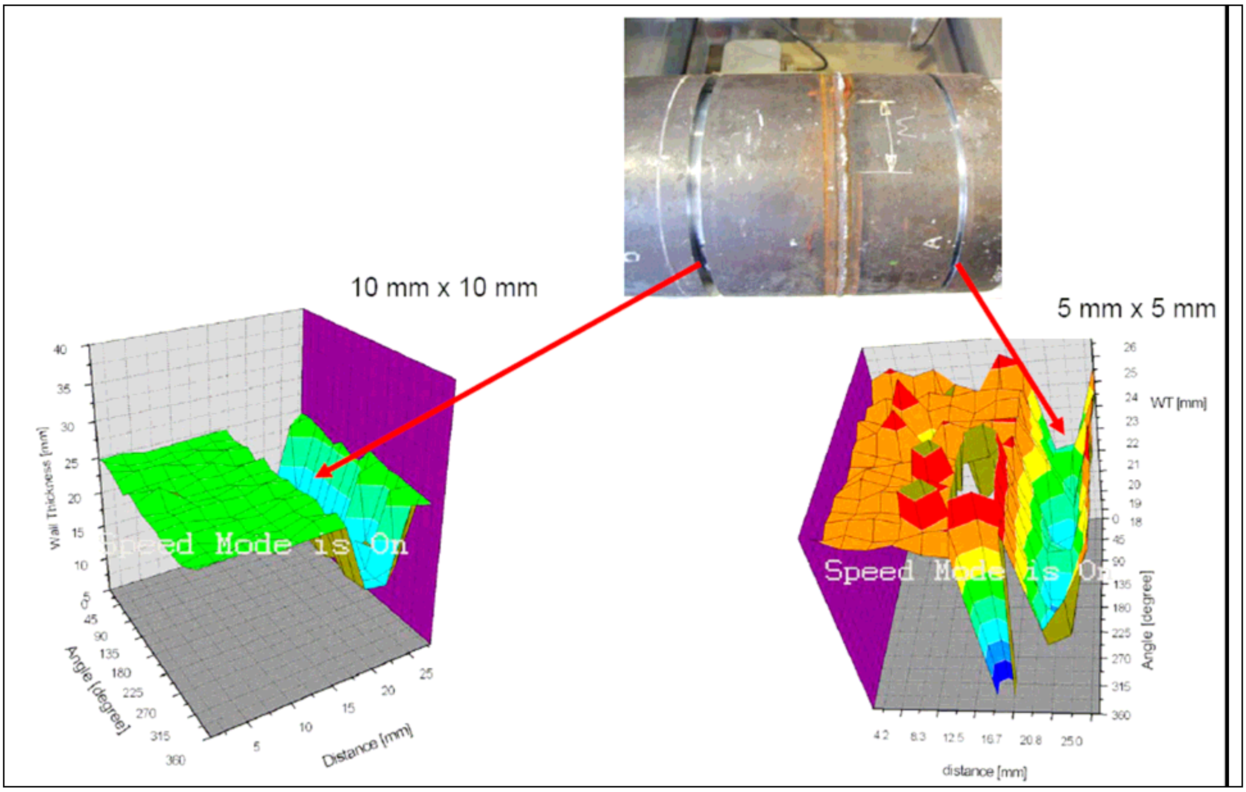

Figure 4. Topographical representation of the sections of 5x5 mm and 10x10 mm constructed for calibrating the measurements on layer thickness of the welds.

Table 1. Results obtained from the calibration procedure (See Figure 5).

$LT_{nominal}$ [mm] *	$LT_{measured}$ [mm]	Comments
(4.78 ± 0.07)	(4.4 ± 2.0)	High uncertainty, experimental improvements underway should overcome this limitation
(9.76 ± 0.10)	(9.99 ± 0.31)	High precision
24.5	(24.2 ± 0.1)	Based on small sections. Experimental improvement may increase precision.

* Uncertainty figures correspond to a confidence interval of 95%.

One problem in the topological representation is the presence of defects. They are seen as intermediate log-normal curves in the A-scan and should be treated by the software. To overcome this problem it was implemented a numerical routine to recognize defects in the A-scan and to distinguish defect from wall reflections.

They are identified in two ways in the A-scan: combined with the log-normal echo of the interface, resulting in a wider echo; and as a distinguishable echo in the middle of the layer and the wall.

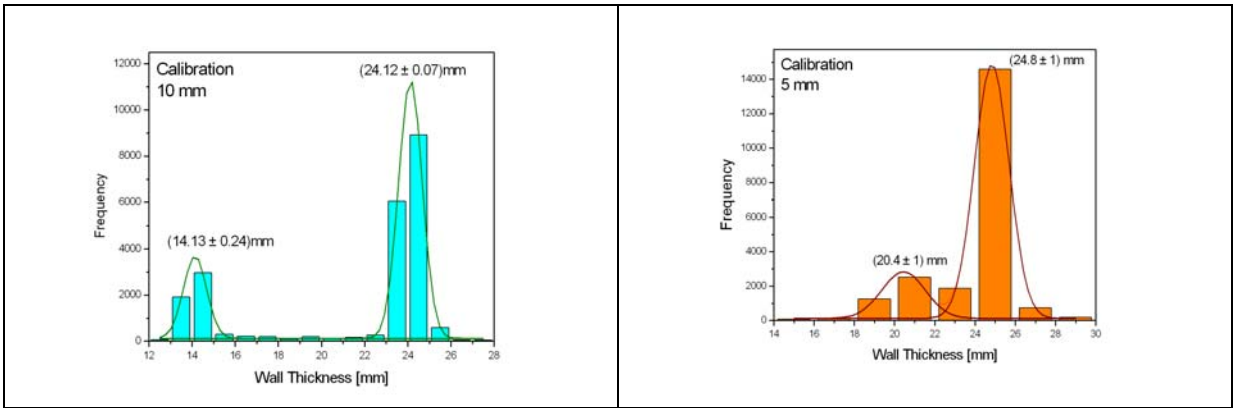

Figure 5. Wall thickness values for the sections of 5x5 mm and 10x10 mm. Mean value is based on a normal fitting. Distances between peaks refer to the WT of the annular section. Uncertainty values (given in Table 1) are given by the some of the LWHM of both gaussians.

Stereovision:

The two eyes located side-by-side in the front of the human face allows each eye to take a view of the same object from a different angle. Therefore, each eye has same and different visual information. Each view is processed by the brain and joint in a single image. This image should be a result of the combination of the two images by matching up the similarities and adding in the differences.

Stereovision, first described Charles Wheatstone in [5], is the process in visual perception leading to perception of stereoscopic depth. This means the sensation of depth emerging from the combination of two slightly different images.

The stereoscopy corresponds to any technique able to record three-dimensional visual information or creating the illusion of depth in an image. This sensation of depth from a two dimensional image is created by representing a slightly different image to each eye. The traditional technique consists in creating a three dimensional image from a pair of two dimensional images. Those images representing two different view of the same object with a minor deviation similar to the eyes receive in binocular vision. Two mains techniques are used:

- The side-by-side: the two images are positioned side-by-side. It allows a parallel view.
- 3D glasses: the two images are displayed in the same position. Two possibilities to differentiate the images either using alternate-frame sequencing or given to each image a different color.

Here, different colors were used to generate the stereovision. The two images are colorized, for instance one in blue, the other in red and assembled. With appropriate colored glasses (blue for one glass, red for the other), it results in seeing, for each eye, a slightly different picture. The blue image will be perceived by the blue filtered eye as black, the red image as white (and respectively white and black for the red filtered eye). White or true black areas are perceived the same by each eye. The brain combines the image received from each eye, and interprets the differences as being the result of different distances, as a normal three dimensional vision.

Results:

The two eyes located side-by-side in the front of the human face allows each eye to
From the wall thickness measured by the PA elements and calculated thanks to our genetic algorithm, the wall thickness of the annular section has been designed. From this wall thickness representation two images have been designed: one with an angle from the left, the other from the right. The result is presented by the figure which can be seen in 3D using special glasses. Those pictures correspond to the calculation of 720 * 32 ToF (1 ToF every 0.5° and 32 elements). This was obtained in 30 minutes using a 3GHz CPU.

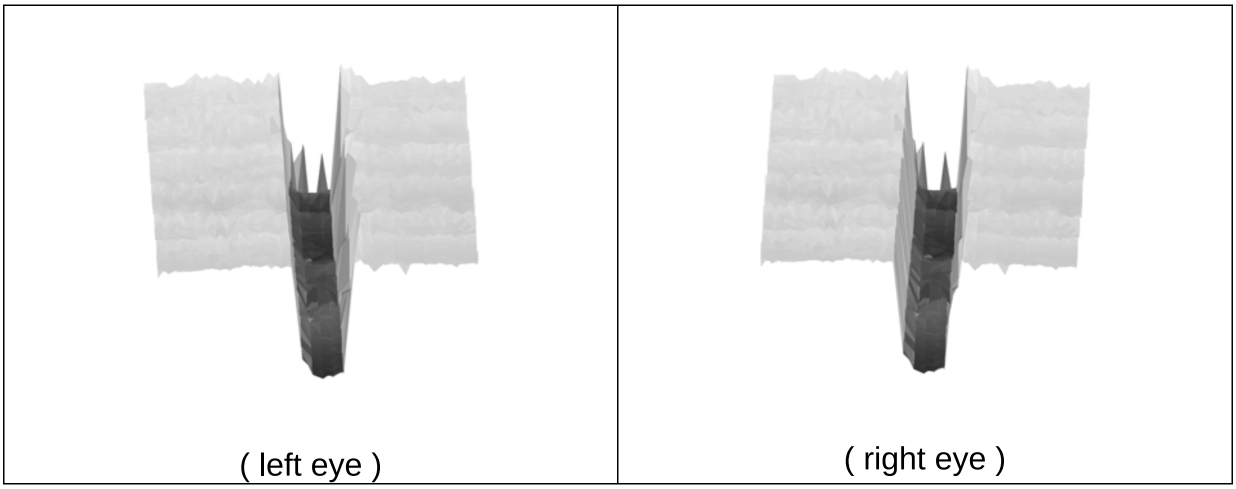

Figure 6. Representation of left and right eye images of the root path of a weld seem.

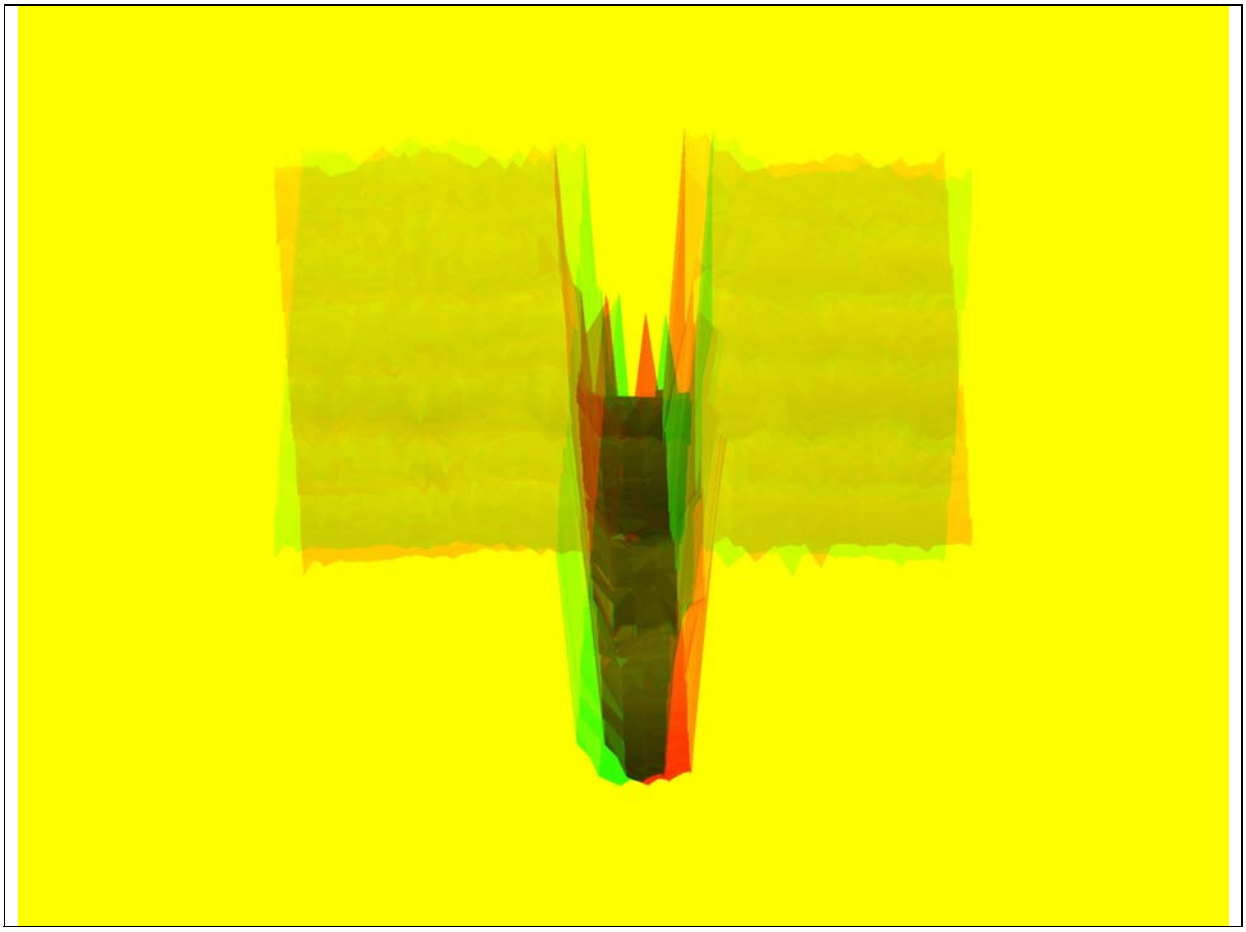

Figure 7. Stereo image of the root path of a weld seam reconstructed from phased array UT data processing. The program used for generating the stereo image is available at http://neuronik.free.fr/Stereo/ .

CONCLUSIONS

The phased array technique has shown its capability to represents a weld beam. The genetic algorithm implemented
From the results it is possible to conclude that:

- The measurements using PA UT inside the tube is not conventional but speeds up the measurements and allows doing ultrasonic experiment outside tanks.
- A different approach was used to calculate the time of flight using genetic algorithms;
- The calibration shows good precision for thin root path (thinner layer);
- A proper stereovision representation of the root path or annular section was performed allowing a visualization of these features.

The advantage of the use of stereo images is to allow visualization in three dimensions of small defects on the root path of welding processes.

Same approach can be used to detect defects, wall thickness deviation and surface problems.

Refeferences

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