

# **APPLICATION OF 2D ARRAYS FOR ULTRASONIC TUBE INSPECTION**

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## **ABSTRACT**

The client demands in terms of ultrasonic inspection on pipes are going more and more in the direction of the detection of flaws with various orientations. The phased array technology allowed during the few last years an evolution in the ultrasonic inspection with an increase of flexibility. The linear phased array transducers allows for example the inspection of flaws with a direction near to the one researched without any mechanical movement of the transducer.

The two dimensional phased array transducers let now the possibility to work in the whole space since it was limited to a plan with the previous ones. With a same position of the matrix transducer, it was demonstrated that the totality of the defect orientation were detectable.

The capacity of such a transducer to product a beam controllable in the space offers then increased possibilities for the tube inspection and allows an important diversity in the inspections with no mechanical setting of the transducer.

**Keywords:** Ultrasound, 2D phased Array, flaw orientation

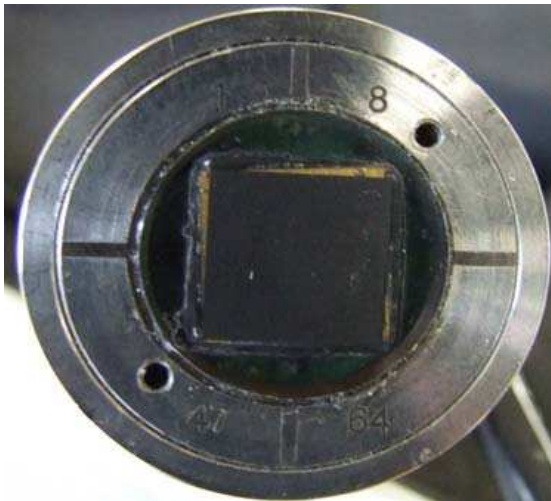
## **1. INTRODUCTION**

During the few last years, phased array technology took a great importance in the evolution of ultrasonic inspections. Within the Vallourec Group, some industrial installations have been in operation for the year 2000 with linear transducers.

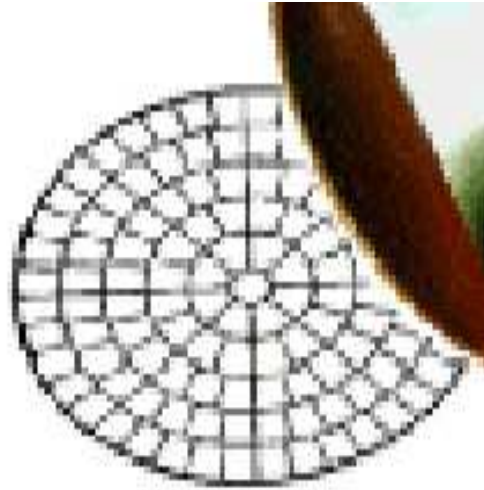
This technology allows the performance of electronic steering, focusing or scanning of the beam in the plan of elements cutting.

Nowadays, phased array transducers evolve and suppliers are proposing some different cutting and layouts of the elements. The target of this new generation is in most of the cases the complete electronic beam control. 2D array transducers offer in this spirit two main advantages that are the possibility to perform several inspections with a same mechanical position of the transducer and a possible acquisition of images provided by those different inspections for each inspection position.

The transducers layouts are very varied but the most common are the sectorial and square matrix presented hereunder.



*Square matrix*



*Sectorial transducer*

Those two types of 2D array transducers allow some improved possibilities compared to the classical phased array transducers:



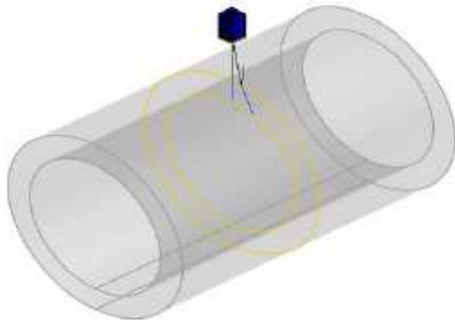
*Classical phased array transducer*

## **2. TECHNICAL POSSIBILITIES**

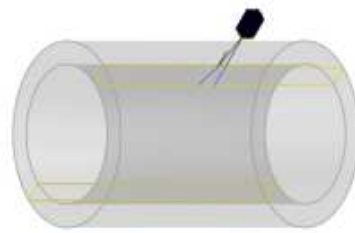
Concerning tube inspection, the main advantage of phased array 2D technology remains the possibility to steer the beam in the whole space. Indeed, since the orientation of the defects can be different depending on the production tools, the inspection needs to be adapted to this orientation. With the use of classical phased array, the defects with an orientation lower than  $20^\circ$  could be detected with the transducer used for longitudinal inspection. Nevertheless, two other transducers had to be added for wall thickness and transversal inspection.

With 2D arrays, the possibility of the transducer to focus and steer the beam in all directions allows the detection of all defects orientation with a central position of the transducer.

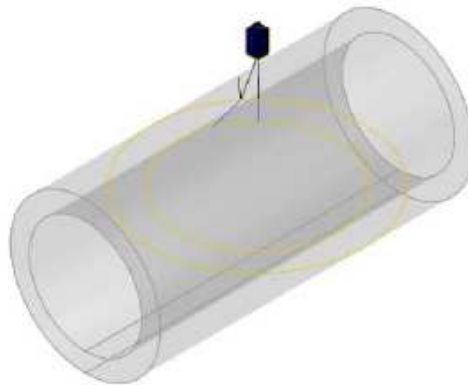
**Different type of inspections with the same transducer (images extracted from CIVA software)**



*Inspection of longitudinal defects*



*Inspection of transversal defects*



*Inspection of oblique defects (eg : 45°)*

We presented the different theoretical advantages of such a transducer. The main advantage remains the fixed position of the transducer. Everything is performed electronically in order to operate the different inspections presented here before.

### **The transducer used for the trials**

The transducer designed for the trials is a square matrix of 64 elements with a frequency of 2 MHz.

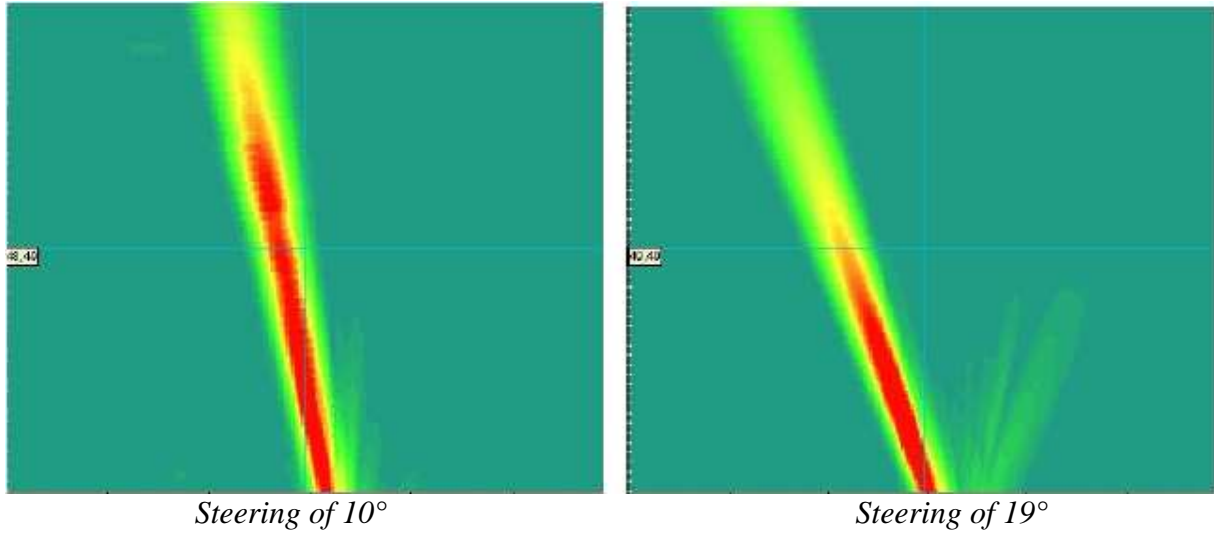


*The transducer used in the trials*

### 3. THE TRIALS PERFORMED

#### Beam steering

The first trials have been performed in water tank in order to visualize the constructed beam with the different configurations. To perform this, a reflector has been moved in front of the transducer in the deflection plan.



This trial has been performed in different steering plans in order to validate the possibility to work in the space and to determine the limits of the transducer in all directions.

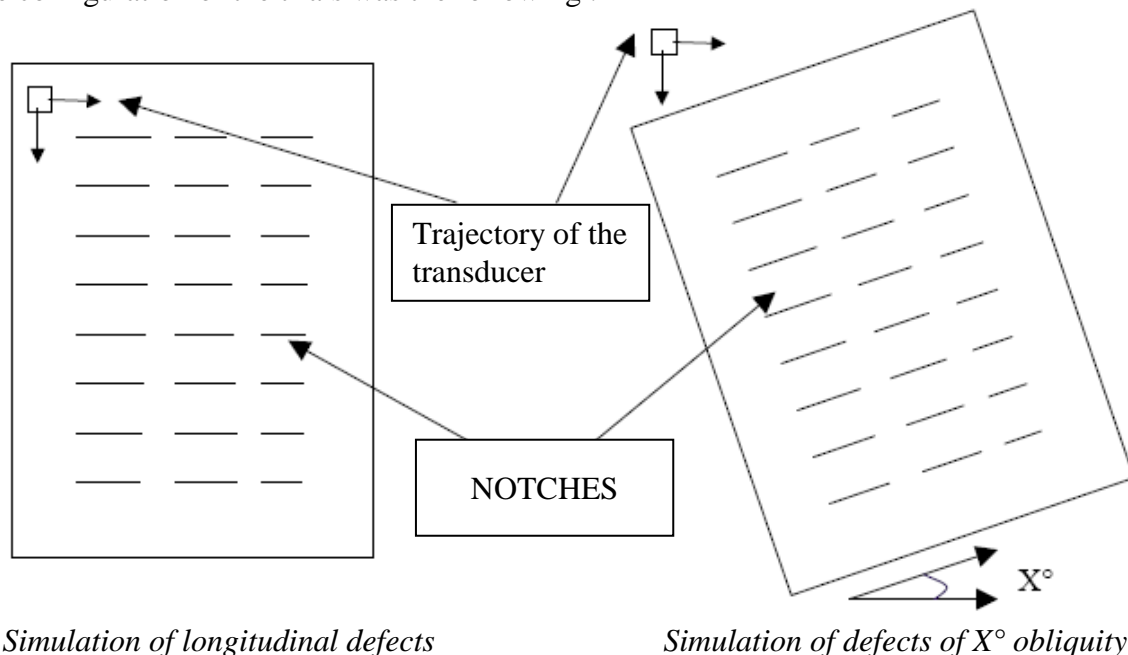
As shown on the figures presented here before, the measurements allowed us to validate the capacity to steer the beam in the whole space and to keep in all configurations (until steering angle of 19°) a good signal to noise ratio.

## Trials on plates

A steel plate of 1 centimetre wall thickness has been used for the following trials. Twenty one electro eroded notches with a depth of 0.5mm and different length have been machined on this sample.

The plate has been placed in different positions in order to simulate some defects in different orientations. The transducer has then been moved in front of the plate with the appropriate delay laws corresponding to the orientation to look at in order to validate the detection of the defects.

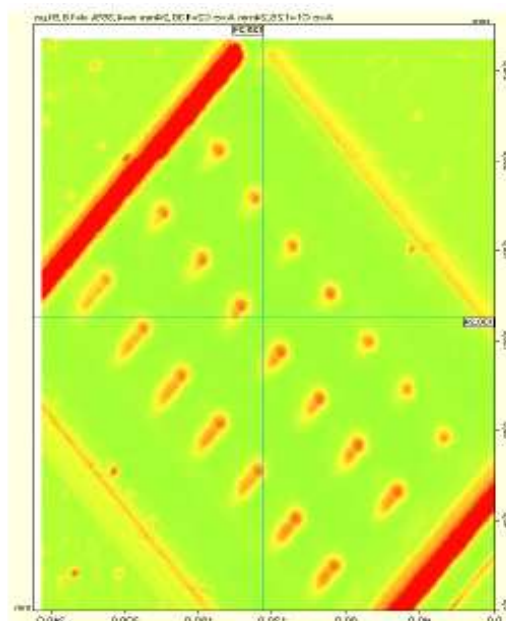
The configuration of the trials was the following :



*Simulation of longitudinal defects*

*Simulation of defects of  $X^\circ$  obliquity*

This trial configuration allowed us to validate the possibility to detect with this transducer different defects orientations.



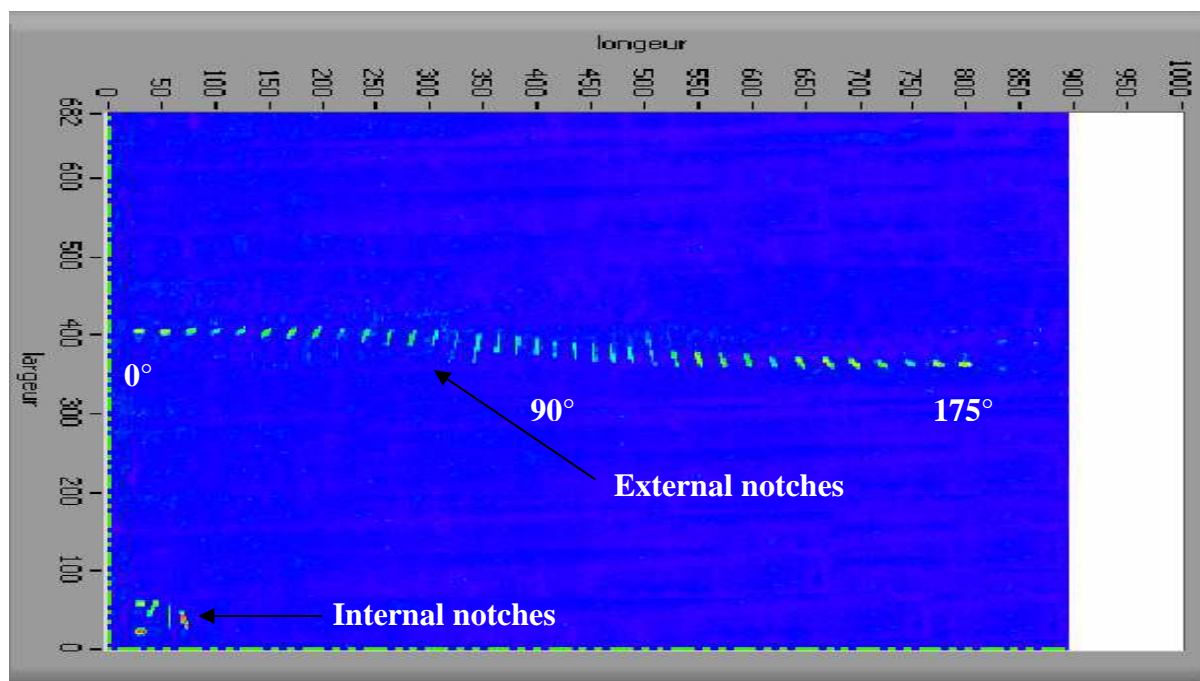
*Example of measurement at 45°*

## Trials on pipes

Following the trials in water tank, a good knowledge of the transducer performances allowed to perform some trials on pipes. The trials have been performed on various dimensions. The presented results concern some measurements performed on a 231 mm diameter pipe with a wall thickness of 10mm. Some internal and external electro eroded notches with 0.5mm depth and different orientations (from 0° to 175° with a pitch of 5° for external ones) were machined on the pipe for the trials. The transducer has been placed perpendicular to the pipe as for a wall thickness measurement.

Some calculations have then been performed in order to determine the different delay laws to apply in order to steer the beam in the direction of the different defects to detect.

The measurements performed show some good results with a detection of all the different orientations of artificial defects with responses presenting a good signal to noise level (>18dB).



*Example of acquisition with the detection of the different oblique notches*

#### **4. CONCLUSION**

First, the capability of the transducer to steer the beam in the whole space has been validated thanks to the performance of cartographies representing this one.

Then, the efficiency of an inspection configuration using this transducer has been demonstrated with measurements performed on artificial defects machined in different orientations. The results showed a good selectivity on the defect orientation and a good signal to noise ratio on defect depth usually used for tube inspection.

Thanks to the trials performed, different possibilities of 2D arrays have been confirmed. The measurements on tube allowed us to demonstrate the acoustic validation of the inspection with such a transducer.

The main advantages identified at this point of the validation are the possibility to detect all the defect orientations with a same transducer and to pilot the transducer fully electronically in order to avoid any mechanical setting.