ULTRASOUND SIMULATION HELPS TUBE MANUFACTURERS TO CALIBRATE THEIR NDT SYSTEMS

S. Deutsch[1], B Bisiaux[1] and P. Gerard[2]
[1]VALLOUREC, Aulnoye, France; [2]VALTIMET LES LAUMES, Venarey Les Laumes, France

Abstract: For certain ranges of small diameter and thin wall thickness tubes, the Snell Descartes laws (where the ultrasonic field is considered as a thin beam) and the operator's experience in ultrasonic testing are sometimes inadequate for calibrating the NDT system.
The opening beam width combined with the small radius of the tube in fact creates several different angles of refraction in the stainless steel tube and causes the beam to widen. For the NDT operator, the signal from the internal and external notches can easily be confused with background noise and the usual solutions for separating signal from noise are useless here.
The CIVA simulation software (developed by the CEA) is an invaluable aid to understanding and visualizing the phenomenon. It makes it easier to find solutions and test their effectiveness in the detection of the notches.
The results of these simulations enable us to guide the operator in calibrating the NDT system.
In this article we examine the case of the ∅19 x 1.20 mm stainless steel tube for which, after several hours of calibration, it wasn't possible to find the right settings. The simulations allowed us to understand the acoustic phenomenon and, working closely with the NDT manager of the plant, try to find a solution.

Introduction: For certain ranges of small diameter and thin wall thickness tubes, the Snell Descartes laws (where the ultrasonic field is considered as a thin beam) and the operator's experience in ultrasonic testing are sometimes inadequate for calibrating the NDT system.
In this article we examine the case of the ∅19 x 1.20 mm stainless steel tube for which, after several hours of calibration, it wasn't possible to find the right settings. The simulations (with CIVA developed by the CEA) allowed us, working closely with the NDT manager of the plant, to try to find a solution.
At the time of the problem in 2001, we had only the possibility to simulate the notch response (with a special module developed for Vallourec by the CEA) and it wasn't possible to simulate easily the UT beams. So we looked for the best parameters but we wasn't be able to see the UT beam to understand the phenomenon.
In this article, we decided to present:

- the simulation of the notch responses with the conclusions in 2001
- the results after the tests in plant
- the simulation of the UT beam and the interpretation in 2002

Results: Aim of the simulations: to understand the plant problem then to find the best parameters to control the stainless tube 19x1,20 mm.

After a discussion with the NDT plant manager, we decided to study the influence of the following parameters:

- incidence angle,
- probe frequency,
- water path.

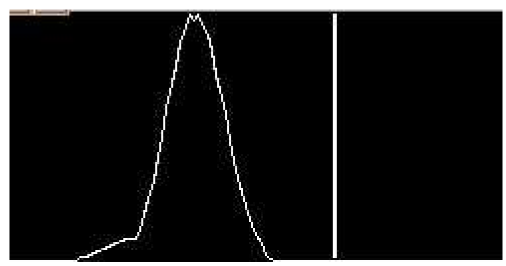
We didn't study the influence of the probe size because our previous simulations showed that:

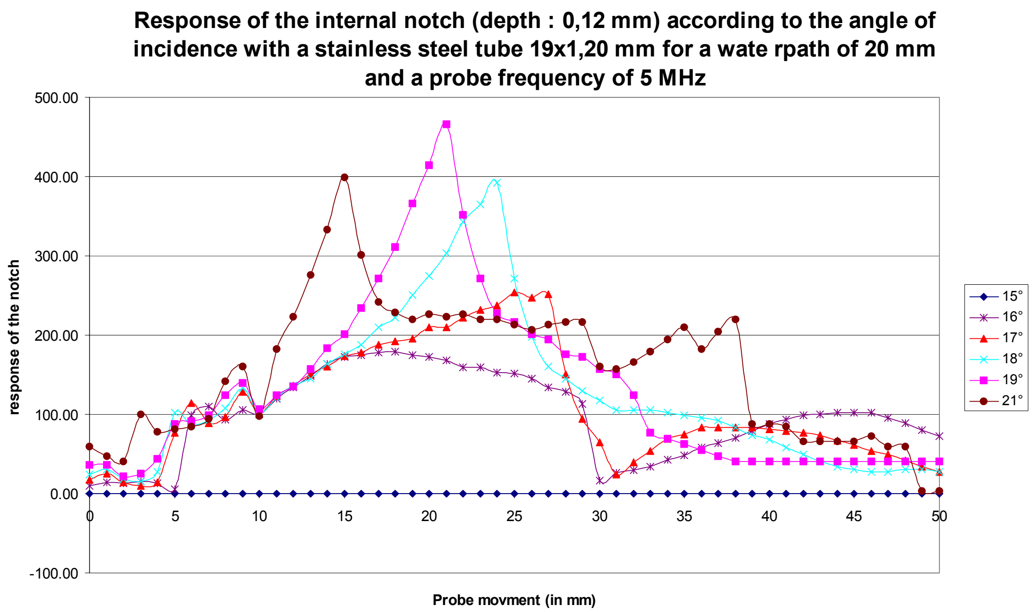
- to increase the probe size downgrades the quality of the field
- to decrease the probe size increases the problem

Reminder of the Control configuration:
Probe: round ∅10 mm of 5 MHz focused at 20 mm
Internal longitudinal notch: depth 0,12 mm
Water path: 20 mm

Notice: on their NDT system, it isn't possible to know accurately the incidence angle. So the NDT operators look for the best angle according to the amplitude of the notches. As a consequence, we study the influence of the angle just to have an idea of the problem.

Influence of the incidence angle: (see diagram next page)
Except for 18° and 19°, we observed a very long response of the notch. In the plant, that corresponds to an increase of noise.
For the two other angles, the notch response is very short compared with a normal echo dynamic (see picture on the right).
As a consequence with CIVA, we observed a problem even if the software detected the notch.
The best angle will be 19° but we have to modify the other parameters to improve the shape of the notch response.


normal shape of the echodynamic



The echo dynamic doesn't have a "normal" shape => we recreate the plant problem.

<u>Influence of the frequency</u>:

For this part, we observe the shape of the echo dynamic and don't care about the amplitude of the response.

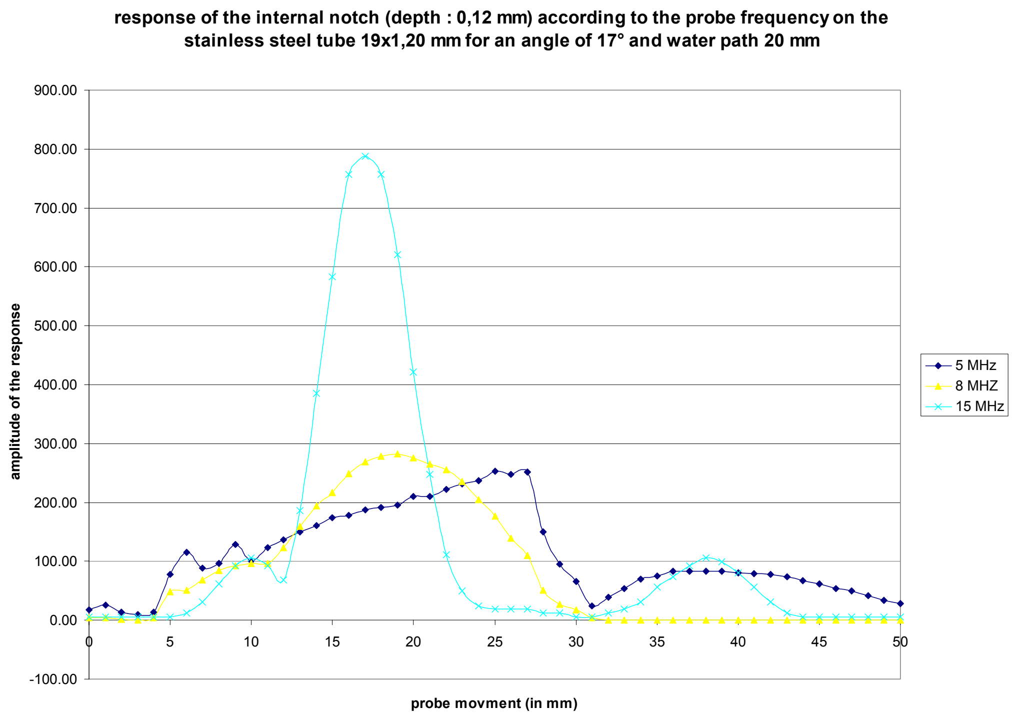
Indeed, in this version, CIVA doesn't take into account:

- the field attenuation which increases with the probe frequency
- the increase of the noise due to the weld

As a consequence, the amplitude seen is far from the reality.

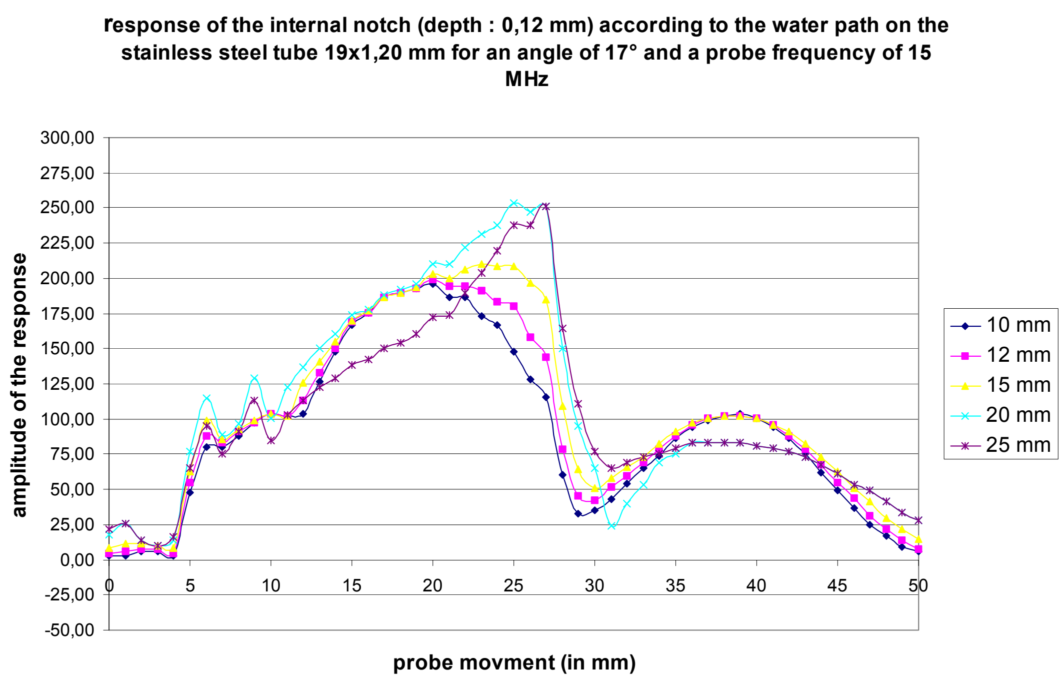
On the diagram, it's obvious that to increase the probe frequency improves the quality of the notch detection.

On the UT bench, we can't use a 15 MHz probe (due to the electromagnetic interference) but we have a 7,5 MHz probe giving a good result according to the simulation.



To increase the probe frequency improves the quality of the notch response. On the UT bench, we prefer to use a probe frequency of 7,5 MHz.

Influence of the water path:
A decrease of the water path improves the shape of the response. Such a parameter seems to be less influential than the probe frequency. But the shape of the response is better so we have to take it into account.



On the UT bench, we will use a water path of 15 mm (the minimum value allowed on the NDT system).

Conclusions:

According to our simulation, the best parameters would be:

- incidence angle: 19° (on the UT bench, the NDT operator doesn't know the angle and so they look for an angle giving a good response) => this result isn't interesting for the plant.
- probe frequency : 7,5 MHz
- water path : 15 mm

We can notice that the most influent parameter seems to be the probe frequency.

Tests in the plant:

We applied these parameters to the UT bench which gave good results. But in fact, for the NDT operator, the parameter the most influential is the water path and the probe frequency improves only the space resolution of the Ascan (phenomenon well known). That means that these simulations gave us the trends but that isn't enough. That's why we need to observe the UT beam to understand.

In 2002, the new version of CIVA allowed us to simulate the UT beams. The importance is to look at the shape of the field to understand the phenomenon. Thus we can better interpret the results.

Analysis of the UT field:

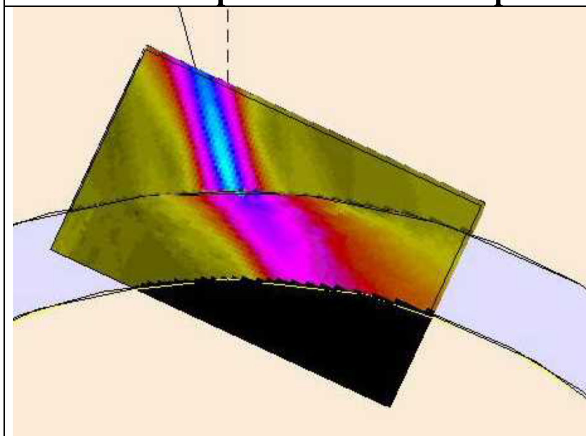
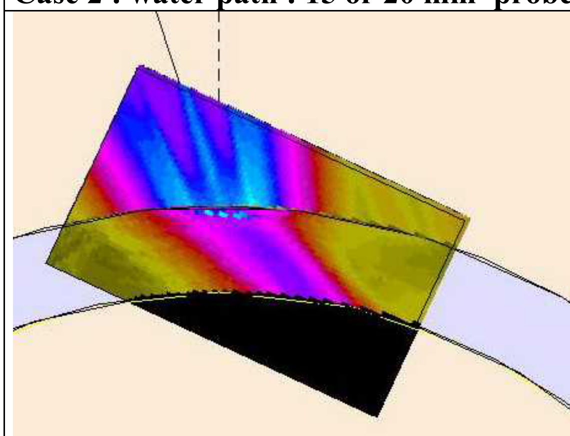
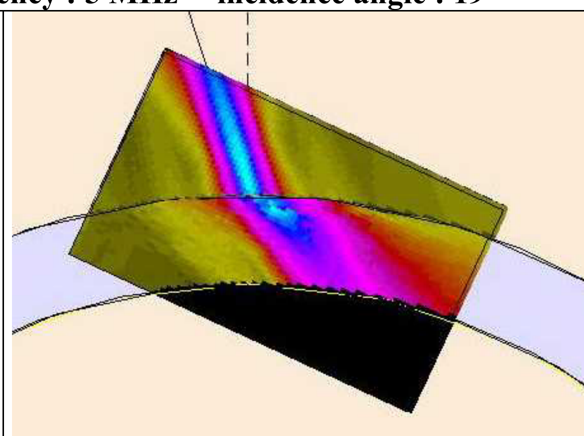
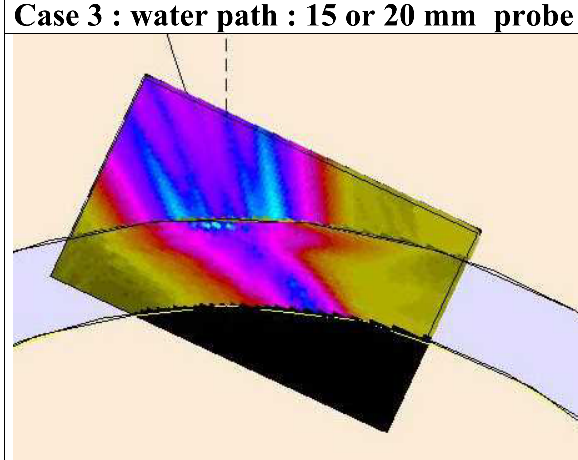
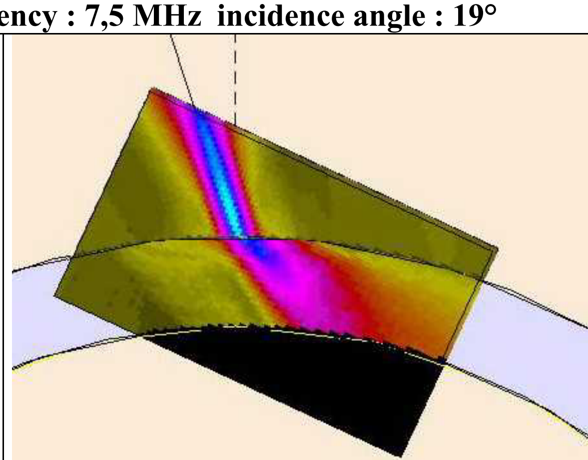
We did some simulations (with several incidence angles, probe frequencies) and the three cases are presented on the next page:

- case 1 : a bad configuration (water path : 20 mm, probe frequency : 5 MHz, incidence angle : 15°)
- case 2 : we look at the influence of the water path with a frequency probe of 5 MHz
- case 3 : we look at the influence of the water path with a frequency probe of 7,5 MHz

Up until this period, in order to control a thin tube with a small radius, it's necessary to have a focus = water path. Indeed:

- the interface echo was smaller
- the width of the beam on the tube compared to the radius should allow having an incidence angle. In the other cases, we have several incidence angles and so several refraction angles. The result would be the impossibility to control due top the noise, the spurious indications ...

These simulations allow us to verify theses theories.

Case 1 : water path : 20 mm probe frequency : 5 MHz incidence angle : 15°	
	
Case 2 : water path : 15 or 20 mm probe frequency : 5 MHz incidence angle : 19°	
	
Water path : 15 mm	Water path : 20 mm
Case 3 : water path : 15 or 20 mm probe frequency : 7,5 MHz incidence angle : 19°	
	
Water path : 15 mm	Water path : 20 mm

It's obvious in these simulations that the main parameter is the water path. We obtain an angle of refraction with a water path of 15 mm and several others with a water path of 20 mm. That's contrary to the theory.
To work with a water path of 20 mm involves a beam opening on the surface of the tube and so several angle of incidence.
On the contrary, at first sight, to work with a water path of 15 mm involves a wide beam and thus too wide compared to the small radius. But in fact, the incidence angles seem to be always roughly the same**. So we have one angle of incidence with a width beam on the tube.**

Without simulations, it isn't possible to see this effect.
We notice too that to increase the frequency gives a beam thinner on the inner surface of the tube for both water paths.
As a consequence, according to these last simulations, the best parameters would be:

1. water path : 15 mm (the most influent)
2. to increase the probe frequency

Discussion: In this case and under plant conditions, the NDT operator thinks it would be better to work with a water path of 20 mm. This configuration allows to have a thin beam with a small radius tube.
At first sight, that's better because:

- the interface echo is thinner with a thin wall thickness
- we have the impression that the thin beam will give one angle of incidence and so there will be one angle of refraction

In reality and thanks to simulations, a water path of 20 mm downgrades the refracted beam quality and gives several angles of refraction (the notch will be seen like an increase of the noise). The water path of 15 mm increases the interface echo but gives one angle of refraction.
The simulation allows to test some configurations to find quickly the best one and also to see the field. That's a faster approach less expensive compared to the plant which needs to have the probes, the tubes … and it isn't possible to see the beam.
It's important to notice that both types of simulation (UT beam and notch response) are complementary. The first allows us to understand the problem and the second to visualise the results of an UT configuration on the notch detection.

Conclusions: With this example, we saw the importance of the simulation to solve an ultrasonic problem.
But here, we used two complementary ways to find the best parameters:

- the simulation of the notch response
- the simulation of the UT beams

In 2001, we had only the notch response (special module developed for Vallourec) and that wasn't possible to simulate easily the UT beams. So our response wasn't complete and we didn't evaluate enough the importance of the water path before the tests in the plant.

We also see it is necessary to work with the both types of simulation to be able to resolve the problem.