43rd Annual UIA Symposium
23 - 25 April 2014 - CSIC, Madrid, Spain

On limitations of the ultrasonic characterization into pieces manufactured with highly attenuating materials

A. Ramos[a], E. Moreno[b], B. Rubio[b], H. Calas[a], N. Galarza[b], J. Rubio[b], L. Diez[a], L. Castellanos[c], T. Gómez[a]

a - *Instituto de Tecnologías Físicas y de la Información (CSIC). Madrid. Spain.*
b - *Tecnalia R & I (Lab. de Ultrasonidos). Miñano (Vitoria). Spain.*
c - *ESIME, Instituto Politécnico Nacional (IPN), México DF, México*

Abstract

- **Some aspects of two Spanish cooperation works funded by DPI & Innpacto Programs of R&D National Plan, are discussed. The objective is to analyze the common belief about than the ultrasonic testing in MHz range is not a tool utilizable to detect internal flaws in pieces made of coarse-grained steel.**
- **In fact high-strength steels, used in some safe industrial infrastructures of energy & transport sectors, are difficult to inspect using the conventional "state of the art" in ultrasonic technology, due to their internal microstructures are very attenuating and coarse-grained.**
- **It is studied if this inspection difficulty could be overcame by finding intense interrogating pulses and advanced signal processing of the echoes.**
- **A solution would depend on drastically improving signal-to-noise-ratios, by applying new advances on: ultrasonic transduction, HV electronics for intense pulsed driving of testing probes, and an "ad-hoc" digital processing or focusing of the received noisy signals, in function of each material.**
- **To attain this challenging aim on robust steel pieces would open the possibility of obtaining improvements in inspecting critical industrial components made of highly attenuating & dispersive materials, in aeronautics, motorway bridges, or new metallic alloys in nuclear area.**

Problems and possible solutions

In industrial strategic applications, with great demands nowadays, the use of certain critical components is needed, where materials of very high resilience and free of failures must be used. Typical examples are the *austenitic steels of high resistance* (alloys with chromium, nickel or manganese) used in components for high pressure in petrochemical, transport and nuclear sectors. These components are difficulty to be inspected with ultrasonic waves due to they are constructed with *highly attenuating materials having internal coarse grains*, and currently only ionizing radiations, with high economic cost and associated problems of personal health and environmental safety, are used.

Nevertheless, improvements could be investigated including the definition of special ultrasonic transducers to optimize the sensibility in these materials, and using predictive simulations of responses. Other aspects to be tested are to optimize the involved transduction control and echo-signal processing, integrating efficient electronics for driving / reception, well adapted to the selected transducers and materials. The driving systems will have to deliver a major energy that in conventional applications with a design of the electrical tuning & coupling giving echoes with acceptable signal-to-noise ratios. Finally, the disposition of specific processing algorithms of signals and beams could be need in some cases with high noise levels.

A first material testing: Several configurations with distinct END equipments and specific transducers were selected for our testing. They were preliminary applied in testing a steel piece with coarse grain in its internal structure, and in a second step on a piece containing artificial flaws. Simple mono-channel inspections were made using pulse-echo and through-transmission in direct contact, to see the viability of an ultrasonic testing. Other experiments were made using phased-array, with equipments of inspection of type multichannel of last generation (Olympus-Panametrics and General Electric).

A generic piece of coarse-grained steel (containing manganese) was analyzing in five points, with five transducers (1, 2.25, 3.5, 5 and 15 MHz), under high-voltage driving. In the figure 1, six of these 25 responses are shown. Three successive echoes appear coming from the opposite wall of the piece. *Effects of scattering* [1] *and attenuation* [2] are present (see the fall and deformation of the successive pulses and in the level of material noise between pulses). Nevertheless, these characteristics in principle *seem to be not excessively strong as for making impossible an ultrasonic testing* and characterization of this type of pieces.

An important effect is that in some cases multiple reflections (reverberation) appear perhaps due to local in-homogeneities in the metallic alloy. It would be needed a deep analysis of these propagation problems in each particular case, because in this area there are not disposable sufficient experimental data [3-4].

Nevertheless, by testing a piece having artificial flaws, with the NDE unit Olympus-EPOCH-6000 and transducers Panametrics (1 to 5 MHz*), it was not possible to obtain useful echo-signals from flaws*, due to the masking by grain noise. In mono-channel testing, uniquely can be detected the flaw when using the through-transmission mode (which is only applicable whit pieces accessible from both sides). In applications where the pulse-echo option is needed, more complex signal processing, array beamforming, or HV driving with selective damping and tuning network [5], could be employed.

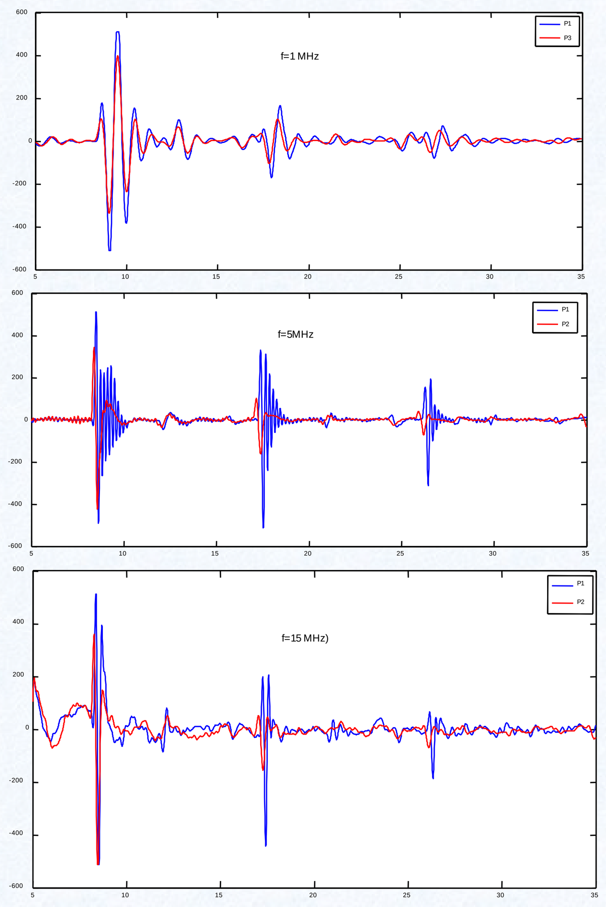

Fig. 1. Echoes in 3 points of the coarse-grained steel piece, with 3 transducers

Ultrasonic analysis with phased arrays

As with mono-channel ultrasonic inspections, it is not possible to inspect in pulse-echo faults inside the piece of attenuating steel, we applied array technologies of our laboratories adapted to this specific case, for dynamic electronic focusing of the ultrasonic beams. The first results, obtained with this multichannel technology of image formation are promising, since faults of 5 mm inside the piece can be clearly detected in pulse-echo. The tests were realized with the models: a) Omniscan (Olympus) with a 36-elements / 5 MHz array, and b) Phasor (General Electric) with a 16 elements / 4 MHz array.
In the Figure 2, some of the obtained results in these array inspections are depicted

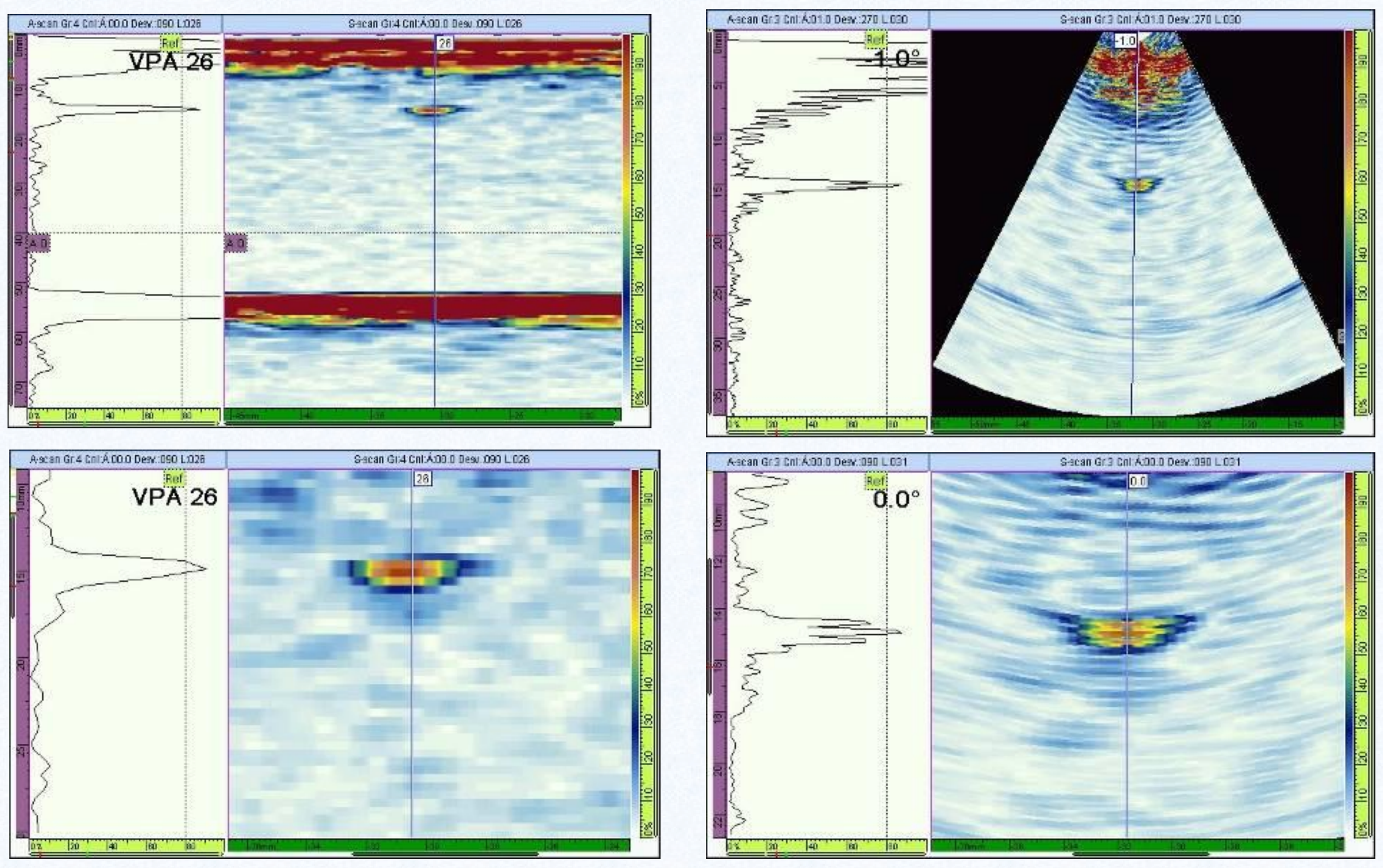

Fig. 2. Some array inspection results with Omniscan for an artificial flaw

Conclusions

From results obtained with our disposable technology, of mono-channel and phased array types, using a manual testing for contact, it seems that some of these option could be valid for the identification of internal flaws in very attenuating pieces. Using improvements in the HV driving-tuning and mainly employing multichannel focusing testing, some flaws around 5 mm in diameter can be clearly detected.

References

[1] P.C. Watterman and R. Truell. Multiple Scattering of Waves. *J.Math Physics*, vol 2 No. 4 Jul-Aug, 1961
[2] P. He. Experimental Verification of Models for determination of dispersion from attenuation. *IEEE-UFFC.* vol 64 No 3, May, 1999
[3] J. Garnier, and K. Sølna, *J. Acoust. Soc. Am.* 127,62, 2010
[4] S. Holm, and Ralph Sinkus, *J. Acoust. Soc. Am.* 127, 542, 2010
[5] A. Ramos, J.L. San Emeterio and P.T. Sanz. Improvement in transient piezoelectric responses of NDE transceivers using selective damping and tuning networks. *IEEE-UFFC*, vol. 47, nº 4, pp. 826-835, 2000

Acknowledgments. To MINECO, Projects: DPI2011 - 22438; and INNPACTO Program / IMAAD - IPT-020000-2010-0004.