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# IMPROVEMENT OF ULTRASONIC EXAMINATION USING THE SPARTACUS SYSTEM

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## ABSTRACT

Improved computer technology and technical advances in data analysis have significatly modifyed the methods employed to perform ultrasonic inspections. The SPARTACUS system developped by the CEA (French Atomic Agency) in an example of this progress.

The nerve center of the system is a graphic workstation. The system permits full digitization of waveform while retaining high data acquisition rates of conventional system. In addition, it enables ultra fast analysis with comprehensive interactive imaging including signal processing (filtering, correlation, deconvolution...), image processing, spectrum analysis, automatic edition of report, 3D presentation.

This system is now use during In-Service Inpection with MIS (In-Service Inspection Machine). Some examples of applications are shown : improvement in sizing capablities, examination of austenitic weldments ; thickness measurement (tube applications...), automatic detection.

## INTRODUCTION

The use of computerized ultrasonic testing over the past several years has helped significantly to enhance the effectiveness of NDT. Conventional systems are routinely used to acquire on the same support both the control parameters of an ultrasonic test and the actual ultrasonic data (maximum amplitude and time of flight of one or more echoes of which the amplitude exceeds a threshold in a validation gate). This type of acquisition is associated with different types of image representation (CSCAN, BSCAN etc), allowing the application of detection and sizing procedures.

In many cases, unfortunately, these systems no longer help to meet the ever-stricter requirements of NDT. Two types of limit may appear.

- The use of a threshod system becomes problematic, if not impossible, if the signal to noise ratio is mediocre (as in high structural noise materials ; composite, oustenitic steel), and if the surface echo of the test piece is disturbed.
- All the techniques of characterization, sizing, or of improving the signal to noise ratio making use of information processing cannot be employed because the complete form of the high frequency signal and hence its frequency content are not accessible.

It is to overcome this type of problem that the SPARTACUS system was designed.

- In acquisition mode, SPARTACUS helps to record all the waveforms continuously in numerical form, and at a rate compatible with industrial requirements.
- In processing mode, SPARTACUS offers the expert vast processing and imaging possibilities, which enable him to set up the analytical method adapted to a specific problem, so that the industrial operator then has a tool capoble of diagnostic automation in complex testing situations.

## ARCHITECTURE

The SPARTACUS acquisition system is architectured around an HP9000 graphic workstation, associated with various peripherals (hard disc, numerical optical disc). Two configurations are possible (fig. 1). One (SPARTACUS basic version) is used to perform acquisition directly with the HP9000 via a parallel card. In the second (SPARTACUS VME version), acquisition is performed by a card installed on a VME bus connected to the computer by a specialized interface. These two configurations differ in their acquisition rate possibilities. The SPARTACUS processing version is itself fully instolled on the HP workstation.

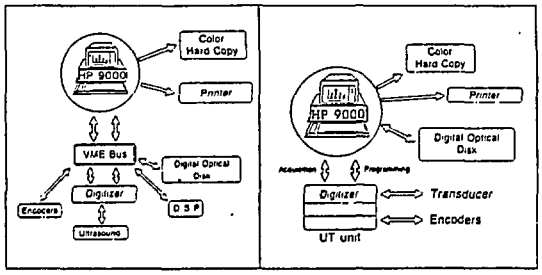


Fig. 1 : SPARTACUS - TWO OPERATING CONFIGURATIONS

## ACQUISITION

The acquisition part of SPARTACUS actually covers three different functions : adjustment, acquisition (reading and storage) and real-time monitoring. Figure 2 shows the graphic screen corresponding to an adjustment phase : it is accordingly possible, in user friendly manner, to modify all the parameters of the ultrasonic circuit or of the digitizer (gain, sampling). The associated multi windowing serves to display simultaneaously the transmission echo and the signal over a considerable depth, the window to the digitized (video or high frequency signal), and the corresponding spectrum analyzer function.

The SPARTACUS basic version corresponds today in optimal conditions to a continuous rate of 200 kbytes/s. The SPARTACUS VME version allows rates of 1 Mbytes/s. During acquisition, real-times imaging with B-C-DSCAN views are available.

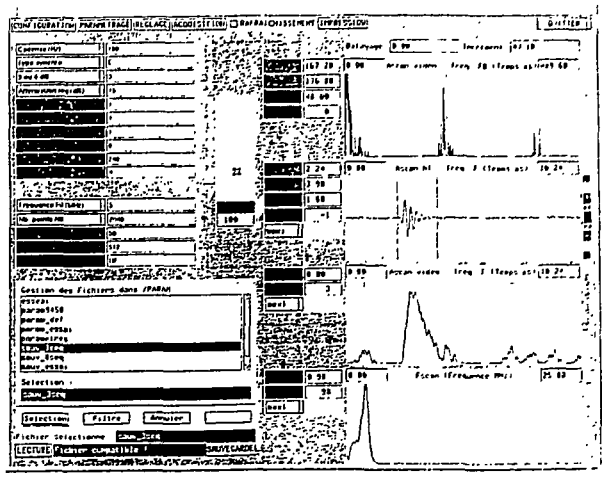

Fig. 2 : ACQUISITION PARAMETERS

## INTERACTIVE IMAGING SYSTEM

Imaging is an important aspect during the analysis of an ultrasonic test. Figure 3 shows the basic image system of SPARTACUS. This example concerns the testing of a block in which holes are drilled (by 60 degree longitudinal wave). The multi windowing system serves to display simultaneously the CSCAN, the DSCAN (side view), the BSCAN, the echodynamics , the ASCAN, and the associated spectral representation. The main characteristic of the system is its very high speed which, by a set of interactive cursors, enables the operator to display the image(s) of interest to him. It is also possible to reconstruct an image by taking account of the transducer refraction angle and the propagation rate in the medium concerned, which helps to determine the positions of the flaws in the thickness of the material. The conventional imaging functions (zoom, thresholding) can obviously be performed, as well as a 3D presentation to display the result of a test in the thickness of the piece (figure 4).

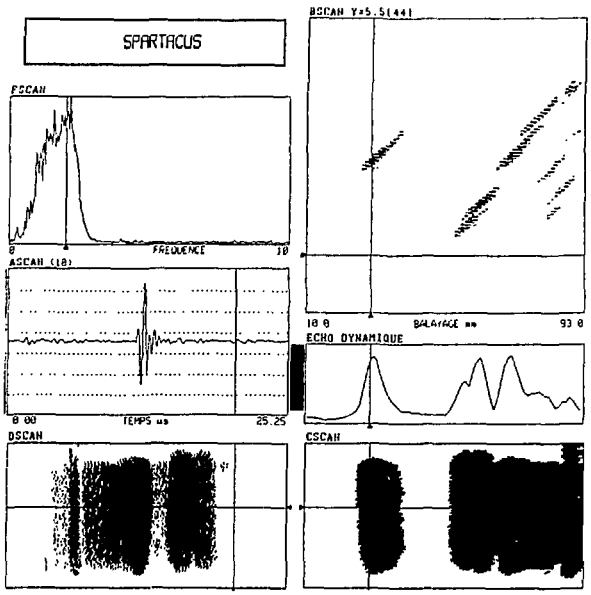


Fig. 3 : INTERACTIVE IMAGING

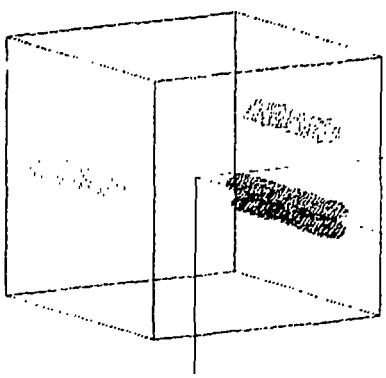

Fig 4 : 3D IMAGING

## SIGNAL PROCESSING

The foregoing section showed that the ASCAN representation of the waveforms was juxtaposed with a spectral representation. This type of representation helps to perform certain processing tasks very simply :

- application of different filtering techniques, using Fourier transform, Hilbert transform, Split Spectrum Processing, ...
- convolution and signal shaping operations
- work on the form of the signal itself and description of the indications in accordance with different characteristics (correlation, time/frequency representation, wavelet transform)

In all cases, the processing can be carried out on all the ASCAN making up the image, and the operator can evaluate the effect of any particular operation on the BSCAN.

## IMAGE PROCESSING

Several operations can be performed under the term image processing. To begin with, it is possible to reconstruct the result that would have been obtained with a conventional threshold system. The BSCAN image is then, segmented after a spatial correlation in accordance with the characteristics of the transducer used. This image processing can also be performed on the entire acquisition, allowing the segmentation of the CSCAN image. This segmentation phase is corresponding practically to the automatic detection stage.

From the point of view of the tester, this phase corresponds to an automatic detection phase. It is accordingly possible to print a report containing the information describing each object. The example in figure 3 is resumed in figure 5 : the B, C and DSCAN images are segmented and a table of results can be printed automatically.

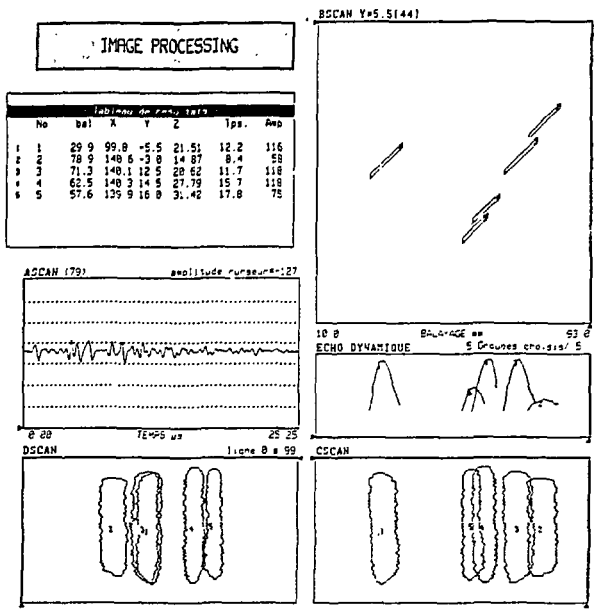


Fig 5 : IMAGE PROCESSING,REPORT PRINTOUT

## APPLICATIONS IN NUCLEAR FIELD

Different application of SPARTACUS in nuclear field can be presented, some of them dedicated for U.T. tube inspection [1], cast stainless steel examination [2], safe end inspection [3] are developped in different paper.

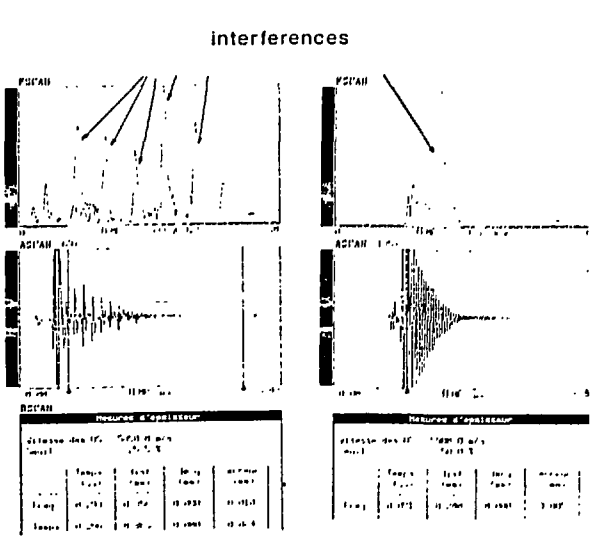


Fig.6 : THICKNESS MEASUREMENT

• Figure 6 : a thickness measurement (longitudinal wave at 0 degree) on a very thin fuel rod. In this example, with the transducer used, measurement in the time domain proves ineffective. By contrast, the thickness can be measured accurately in the frequency domain (peak due to interferences between the signals)

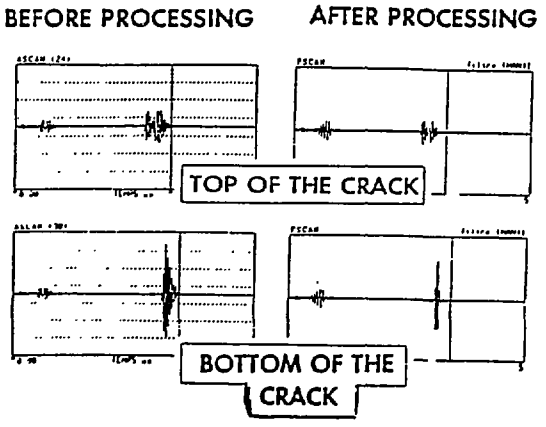


Fig.7 : SIGNAL SHAPING

• Figure 7 : the second example shows the test of a crack with a 45 degree transverse wave transducer. The initial signal is reformated by deconvolution. The comparison of the images before and after processing is revealing : it is clear that the axial resolution is improved significantly and that the possibilities of characterizing the crack (polarity inversion of diffracting edges) are available.

Another example is shown in figure 8 : testing a crack in a noisy austenitic steel (45 degree transverse wave transducer). The image is processed to obtain first an image in which all the indicatians present are segmented, including those representative of the structure noise. This makes it very easy to extract the useful indications from these objects, thus providing the entire signal dynamic range.

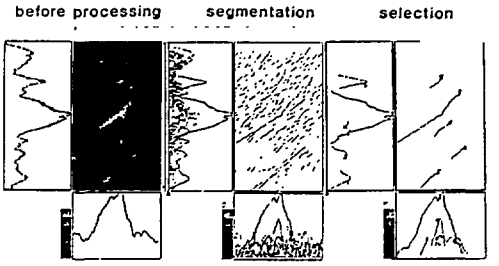


Fig.8 : AUSTENITIC STEEL EXAMINATION

Another example is proposed with the pressure head penetration examination. The use of SPARTACUS for penetration inspection associated to the MIPAC tool gave very good result and relevant information about size, localization of cracks.

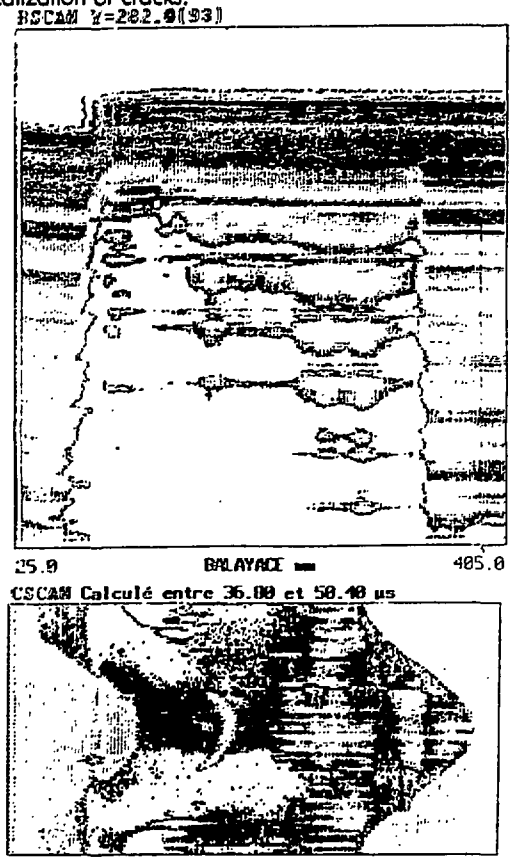


Fig.9 : PRESSURE HEAD PENETRATION U.T.INSPECTION

## CONCLUSION AND PROSPECTS

Advances in information processing, combined with long experience in ultrasonic acquisition and analysis, have helped to build an original, high performance tool which considerably improves the resolution of delicate NDT problems, sizing and characterization of flaws during ISI, austenitic steel examination, low thickness component inspection. The performance of the system is so effective (high acquisition and processing rates) that SPARTACUS can be used as a laboratory tool or as an expert system in an industrial environment.

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[1] Improvements of the Tubes UT Inspection Using a Rotating Probe and Data Processing
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