APPLICATIONS COURANTS DE FOUCAULT DU SYSTEME TEDDY + AVEC DES SONDES ARRAY

ET ARRAY PROBE APPLICATIONS WITH TEDDY+ SYSTEM

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Résumé

Les derniers progrès réalisés dans le domaine des sondes de Courant de Foucault, concernant les sondes array et les sondes avec l´électronique embarqué exigent des systèmes de Courant de Foucault capables de contrôler cette émergente technologie.

Dans ce sens, l'appareil de contrôle TEDDY+ de Tecnatom a été pensé dès sa conception pour pouvoir faire face à cette technologie array. Les puissants et flexibles dispositifs inclus dans le système TEDDY+ d'acquisition de Courant de Foucault lui permettent de contrôler des sondes array d'une manière très simple. Selon les conditions d'inspection, la combinaison des multiplexeurs externes et des modes d'injection permettent qu´avec la version la plus simple de TEDDY+, un array de 64 éléments puisse être piloté.

Le logiciel responsable de l'acquisition et de l'analyse de données a été mise à jour, pouvant définir un canal array comme une combinaison des différents éléments présents dans une sonde array, l´étalonner, etc...

Les résultats obtenus avec différents types de sondes array fonctionnant avec le système TEDDY+ sont présentés dans cet article. Des résultats de différentes applications sont décrits, comprenant l´inspection d´une grande surface, contrôle de fil de fer chaud et l'inspection de tubes de générateurs de vapeur et condenseurs.

The last advances made in the field of eddy current sensors, regarding array coil probes and embedded electronic probes demand eddy current systems capable of managing this emerging technology.

In this sense Tecnatom's TEDDY+ tester was thought from its design to be able to cope with this array technology. The powerful and flexible features included in the eddy current acquisition system TEDDY+ have enabled it to manage array probes in a very easy and straightforward way. According to the inspection requirements, the combination of external multiplexers and injection modes enable that with the simplest version of TEDDY+ tester a 64 array coil can be driven.

The software application in charge of data acquisition and analysis has been updated, being able to define an array channel as a combination of the different elements present in an array probe, calibrate it, etc.

The results obtained with different types of array probes working with TEDDY+ system are presented in this paper. Results from different applications are described including large surface area inspection, hot wire inspection and steam generators and condensers tube inspection.

Introduction

In the last decade the use of eddy current array (ECA) technology has been extending to all industrial sectors. The benefits of such technology are well known, reducing inspection times, being able to cover a large area in one single scan and improving the probability of detection. Even more, flexible array probes based on thin film technology are able to adapt their shape for the inspections of complex geometries.

TEDDY+ ET tester has been designed to interface with the latest generation of probes enabling, thanks to its modular concept, the ease of introducing new probe models that might appear in the future. When working with eddy current arrays several factors are basic in order to decide the best configuration of the equipment: the number of coil elements, scanning speed, number and value of the exciting frequencies and description of external multiplexers to be used.

In this paper three different applications are presented using eddy current arrays and Teddy+ data acquisition system.

- a large component inspection
- hot-wire inspection, and
- Steam Generators and Condenser tubes inspection.

ET Array Probes and Teddy+

Eddy current array technology is the ability to place a number of coils in the same probe assembly. Almost any type of coil is susceptible to work in an array and different working modes are possible, like emitter-receiver mode, differential mode and absolute working mode.

Data acquisition is performed by multiplexing the eddy current sensors in such a way that mutual inductance (cross-talk) between the individual sensors is avoided.

TEDDY+ can manage up to 32 coils with no external multiplexers and up to 256 using 8x1 external multiplexers or 512 using 16x1 multiplexers, operating from 10Hz to 10MHz with the option of using multiple frequencies on the same acquisition. It has up to 32 time slots, two independent generators on each transmitter board, and up to three different injection and or reception modes multiplexed, simultaneous or a combination of both which is named context switching mode.

On figure 1 it is shown a schematic of how ECA are connected to TEDDY+ using external multiplexers, two TEDDY+ connectors will be used, the digital I/O for triggering the multiplexer and controlling the reset, and the probe connector to inject the frequencies and receive the signals from each one of the individual coils.

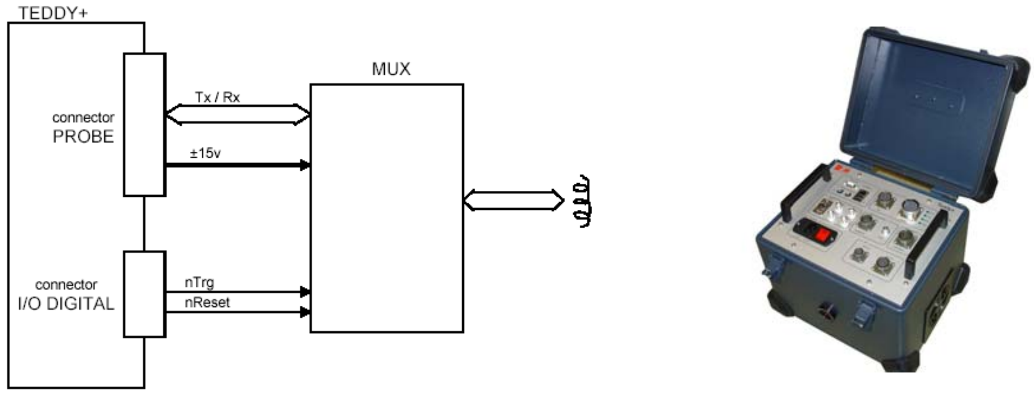


Figure 1 Connecting an ECA to TEDDY+

Software Array Functionality

In order to manage the information coming from ECA, it is necessary to implement adequate functions to manage the great amount of information coming from this type of sensors in an easy way.

So far TEDDY+ software has been updated in order to be able to acquire data using ECA, with or without external multiplexers and to represent data from each channel (a channel is the result of exciting a coil at a certain frequency) individually in strip-charts and lissajous formats.

Additionally some tools have been developed on the analysis part enabling:

- To load a particular eddy current array configuration.
- To calibrate the eddy current array
- To define an array channel as the combination of each one of the different coils
- To view the array channel in lissajous, strip-charts and C-Scan type of representations.

Applications and results

Large components inspection

In the case of large components, the use of array probes implies a clear competitive advantage with regards to punctual probes since it enables much faster inspections as well as the inspection of complex geometry surfaces.

The application presented corresponds to the inspection of the J- weld Groove of the vent pipe, being the scope of the inspection all the weld area and its interface with the cladding (see figure 2).

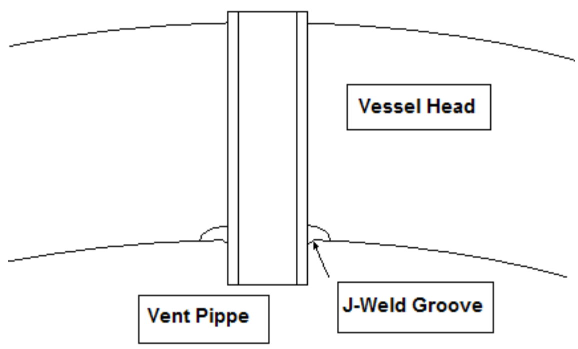
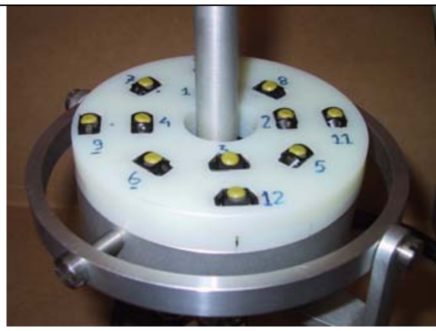


Figure 2 Sketch of the J-Weld groove to be inspected

The purpose of the multi-coil array developed by Tecnatom is the detection and characterization in length, arc, radial position and circumferential position of any crack open to the inspection surface and originated in the intersection weld of the vent pipe of the vessel head.

In the following table a description of the eddy current array is included.

Type of sensor	Description and results	Array sensor
Plus-point coil	Based on commercial plus-point coils, Tecnatom has proposed this type of coil, composed of two coils forming a cross. They have been mounted in an array as shown in the figure. Able to detect defects in any orientation.	

In this case a TEDDY+ tester with four inputs (basic TEDDY+ architecture) is used in combination with three 4x1 external multiplexers. In the following figure on the left it is shown the multi-coil element inspecting a J-Groove mock-up and on the right a C-Scan output of the acquisition.

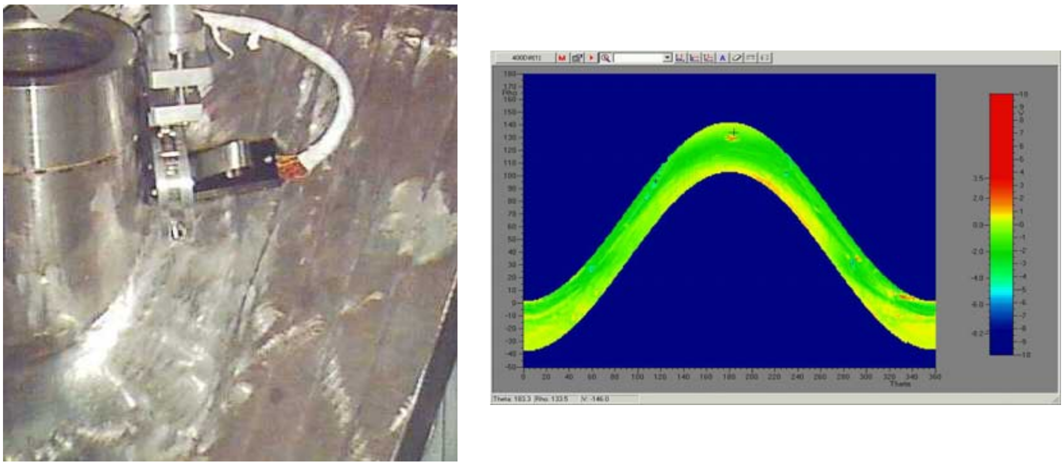


Figure 3 a) Multi-coil element J-Weld Inspection and b) C-Scan Representation data output

Hot wire inspection

In-line hot wire inspection is the first quality control applied in the steel industry to this material before being treated or delivered to the customer. Although actual techniques can detect most of the surface defects produced in the rolling process or before, some critical defects (periodic and very large longitudinal defects) are not detectable by the present systems. The direct consequence of this is that the rejection rate in further quality control (visual inspection, cold drawings, etc.) is higher than expected when in-line hot wire inspection results are evaluated.

The basic components of an inspection system for hot-wire inspection are illustrated below. After the hot wire rod leaves the last mill stand on its way to cooling and coiling, a hot metal detector (or any other device) detects the approach of the rod to the test coil assembly and triggers the eddy current electronics. The rod passes through the test coil and the eddy current signals are transmitted to the eddy current tester, where they are evaluated, and the test results are stored.

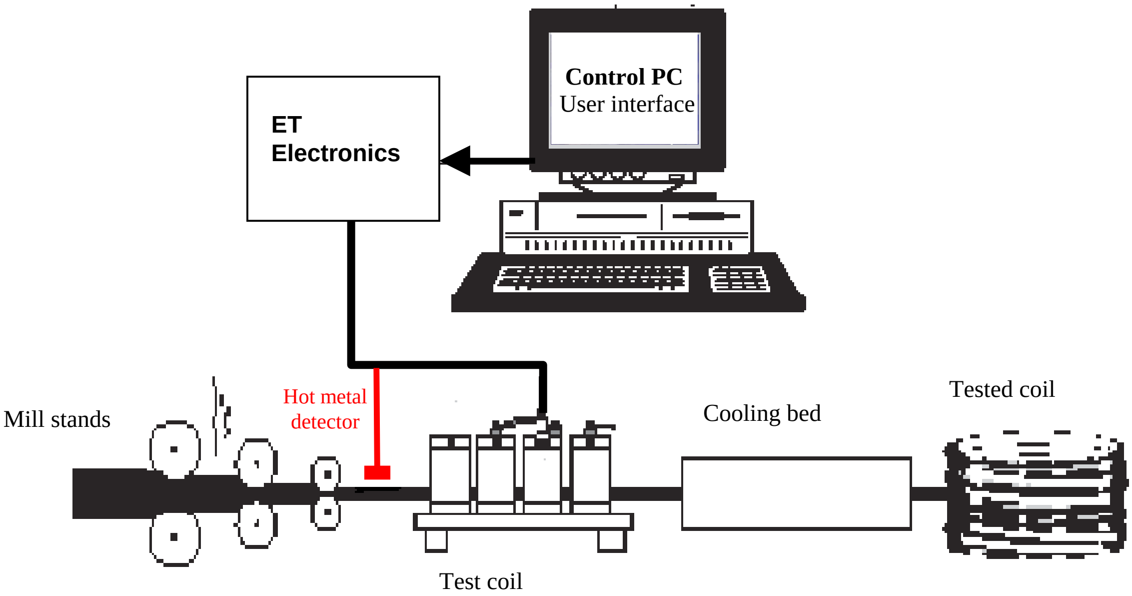
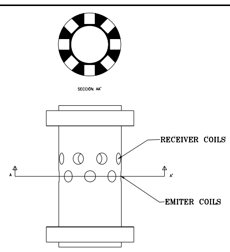
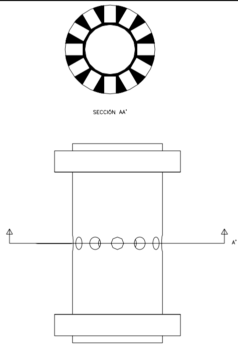


Figure 4 Components of an inspection system for hot-wire inspection

The eddy current technique used in existing rolling mills for hot-wire inspection is based on encircling coils. Basically the eddy current sensor is composed of an encircling coil as emitter and two encircling coils in reception, connected in differential mode to reduce the effect of vibration. This system shows important difficulties for detecting long defects in general (and longitudinal defects in particular)

Tecnatom has proposed and developed two eddy current arrays to improve the detection capabilities of current inspection systems inside an European project named Incosteel (1). The principle and description of these arrays is included in the following table.

Type of sensor	Description and results	Prototype	Array sensor
3-coils sensor	Developed, especially for the detection of longitudinal defects (although other defect orientations are also detected). One coil is used for excitation and the other two in reception (differential mode). Cold and hot tests (as part of a complete array) available. Good performance.		

Plus-point coil	Based on commercial plus-point coils, Tecnatom has proposed this type of coil, composed of two coils forming a cross. They have been mounted in an array. Cold and hot tests (as part of a complete array) available. Good performance.		

The array sensors performed quite well (see figure 4). The aim of these sensors was the detection of longitudinal and very long defects (that could even appear from the beginning to the tail of the coil). A defect of such characteristics, in an array sensor, should change the balance point in the channel (element) that is detecting it. On figure 5 the results over a particular rod with plus-point array are shown. In this preliminary inspection, it has been observed that the balance point (no defects) during inspection is slightly different than the calibrated balance point, having a different behaviour in the different channels. For this reason a research on data processing algorithms is being conducted in order to correct the balance point observed in real operation compared with the calibrated one.

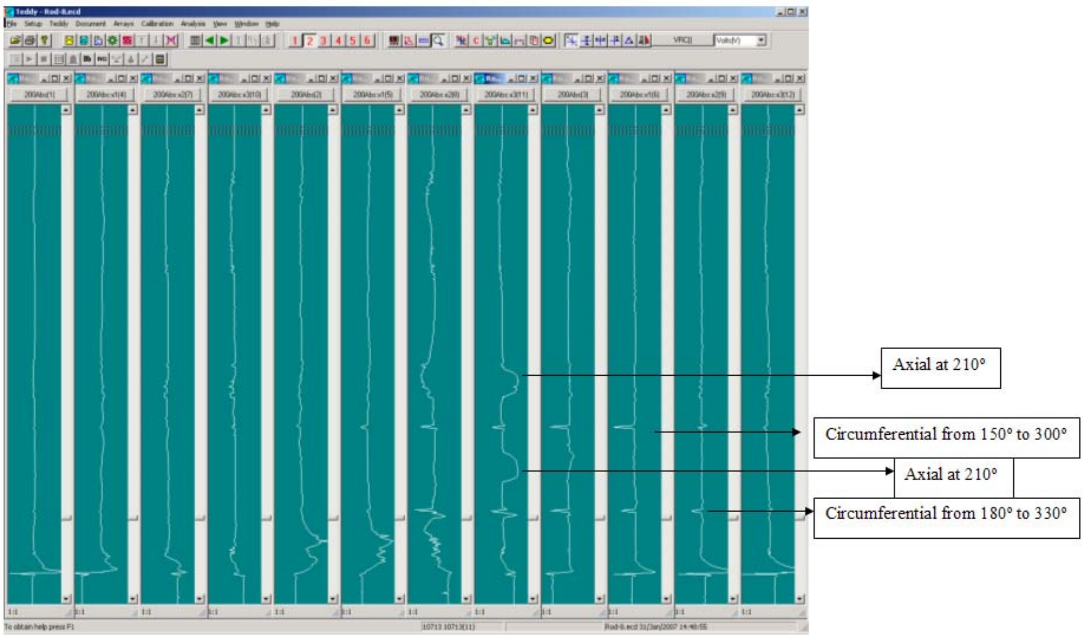


Figure 5 Results with the plus-poin array sensor and rod 8

In the case of this application, hot wire rod inspection, the benefit of using eddy current array probes is clear since it improves the detection capability of current inspection systems, being able to detect long defects.

Steam Generator and Condensers Tubes Inspection

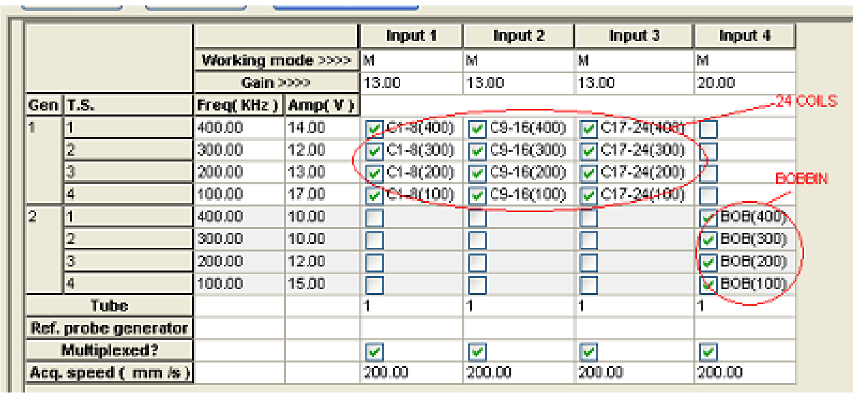
Steam Generators inspection has been traditionally evaluated by bobbin probes 100% of the tube length and by motorized rotating probes in those places susceptible of having circumferential cracks, like tube expansions in the tube sheet, some supports, bends, etc, or simply when there is a need of improving the characterization of a crack (axial or circumferential orientation, arc, length, etc). This fact implies that those tubes must be inspected twice, once with bobbin probe and a second one with motorized rotating probes. If we add to this, the fact that the scanning speed of rotating probes is about 2/100 of bobbin probes we will perfectly understand the benefits of using ECA probes for small diameter tube inspection, to reduce considerably inspection times and dose.

The application presented is the integration of I-Probe (commercial array probe from MHI) together with TEDDY+ with 4 inputs and one 8x1 multiplexer.

Type of sensor	Multiplexers	Array sensor
I-Probe	One 8x1 external multiplexers 	

The I-probe is a multi-sensor, since in the same head it has a bobbin coil and an ECA made of 24 elements. TEDDY+ has the possibility of multiplexing some of the sensors while others not. It also has the possibility of independently trigger each one of the sensors; this means that the bobbin could be triggered at a certain acquisition rate whereas the ECA could be triggered at other. Thanks to the time-stamp being part of the data frame, it will be possible to balance the different channels information. By the moment all these possibilities have been implemented in the acquisition software but future work is needed on the side of analysis software.

In figure 6 the configuration of TEDDY+ for I-probe is shown, three inputs are used with external multiplexers to drive the 24 coils of the ECA while the fourth input is used for the bobbin probe, each sensor is excited with four different frequencies (100 to 400 kHz).



				Input 1	Input 2	Input 3	Input 4
		Working mode >>>>		M	M	M	M
		Gain >>>>		13.00	13.00	13.00	20.00
Gen	T.S.	Freq(KHz)	Amp(V)				
1	1	400.00	14.00	C1-8(400)	C9-16(400)	C17-24(400)	
	2	300.00	12.00	C1-8(300)	C9-16(300)	C17-24(300)	
	3	200.00	13.00	C1-8(200)	C9-16(200)	C17-24(200)	
	4	100.00	17.00	C1-8(100)	C9-16(100)	C17-24(100)	
2	1	400.00	10.00				BOB(400)
	2	300.00	10.00				BOB(300)
	3	200.00	12.00				BOB(200)
	4	100.00	15.00				BOB(100)
Tube				1	1	1	1
Ref. probe generator							
Multiplexed?				✓	✓	✓	✓
Acq. speed (mm /s)				200.00	200.00	200.00	200.00

Figure 6 TEDDY+ configuration of I-Probe

Figure 7 shows the configuration of an array channel showing which coils belong to the array channel and the physical configuration (circumferential and axial offset) of each one of the coils in the array.

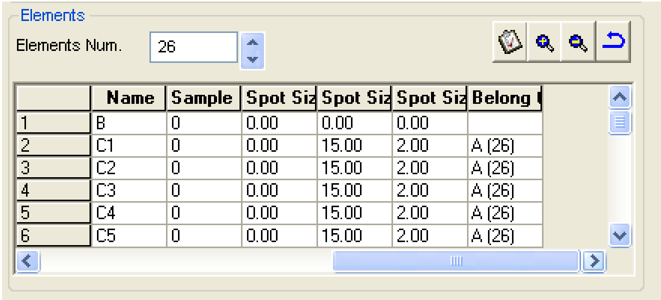


Figure 7 Coils configuration for I-Probe

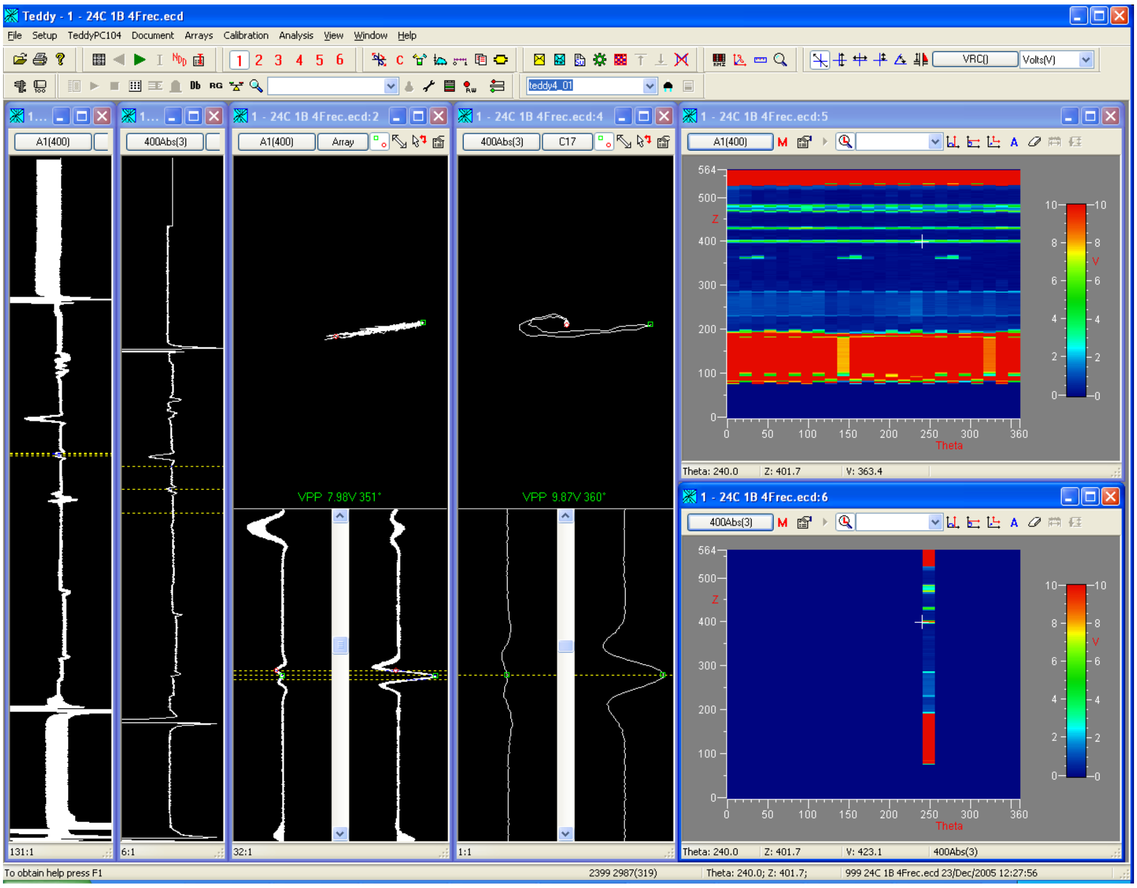


Figure 8 Strip-chart, lissajous and C-Scan representation of an array channel corresponding to the I-Probe

Conclusions and future work

The benefits of using ECA technology have been demonstrated with three practical applications. The powerful and flexible features included in the eddy current acquisition system TEDDY+ have enabled it to manage array probes in a very easy and straightforward way. Even with the simplest version of TEDDY+ tester a 64 array coil can be driven.

Tecnatom will continue with the investigation of new eddy current arrays alone and in collaboration with third companies. At the same time additional software tools will be developed to support eddy current array data analysis.

Acknowledgements

[1] The results of the hot-wire rod application are being developed under an European Project named Icosteel (RFS-CR-04018) in the Framework of the Steel Research Programme.