EDDY CURRENT ARRAY PROBE DEVELOPMENT FOR NONDESTRUCTIVE TESTING

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Abstract: The inspection of materials used in aerospace, nuclear or transport industry is a critical issue for the safety of components exposed to stress or/and corrosion. The industry claims for faster, more sensitive, more flexible and cost-effective techniques. New technologies based on eddy currents (EC) array probe could be a good solution by producing in real time a "magnetic image" revealing surface-breaking flaws or buried flaws on work pieces with complex shapes. This paper presents recent progresses in the development of array probe for aeronautical domains. The CEA has developed, in partnership with CYBERNETIX and EUROCOPTER, an innovative system named CODECI for the inspection of surface breaking flaws. The device includes an array of EC coils and a high resolution camera, to provide a complete and reliable description of potential flaws in real time. The detection of notches contained in various alloys is good, and the accuracy of the flaw depth is about 0.2 mm.

Introduction: The development of eddy currents (EC) array probes is an active field of research and is motivated by the numerous advantages of this technique: it allows an increase of the scanning speed and a better imaging quality, and thus decreases inspection-time and improves diagnosis reliability.
The CEA has been involved for a few years in the realisation of new EC array probes for non destructive testing [1, 2]. This paper presents one example concerning the recent progresses in developing array probes and dedicated to aeronautical applications. The CEA has developed, in partnership with CYBERNETIX and EUROCOPTER, an innovative system named CODECI to replace dye-penetrant inspection on production lines as well as to provide an expertise tool for in-service inspection [3]. The main feature of this system is its ability to combine in real time two different techniques, an EC array probe and a high-resolution camera, in order to enhance the characterization of small surface breaking flaws.

Description of the system: The CODECI system is based on a real time PC platform, and accept several kinds of duplex probes (optical and EC). A general view of the system is given in figure 1.

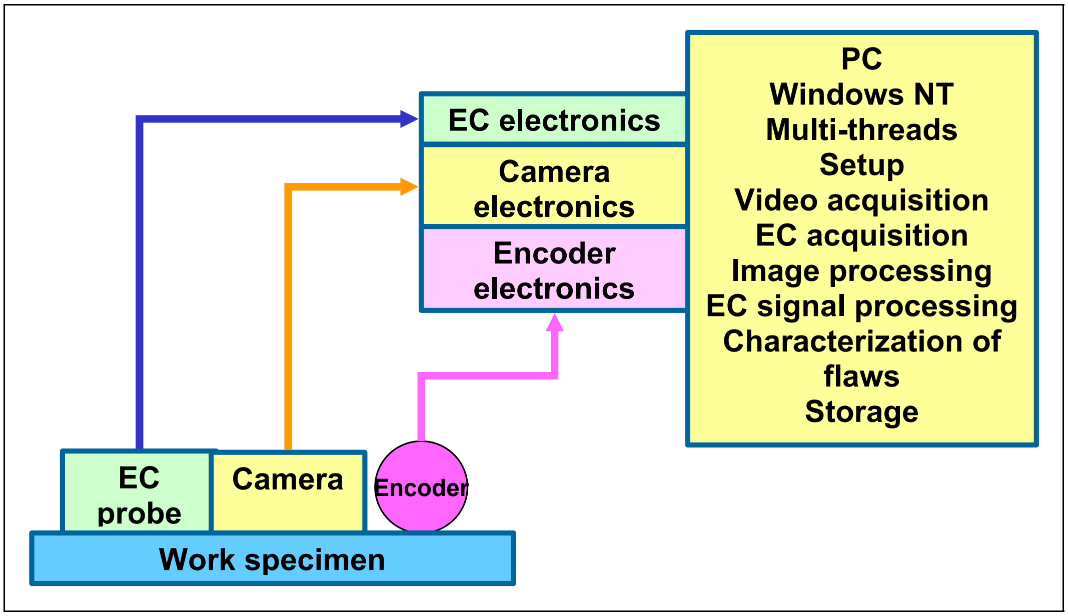

Figure 1: General architecture of the CODECI system.

The CODECI probe is based on a miniaturized and high resolution camera (15 µm), and an EC array probe. A photograph of the probe and a general view in position over a helicopter gear housing are given in figure 2.

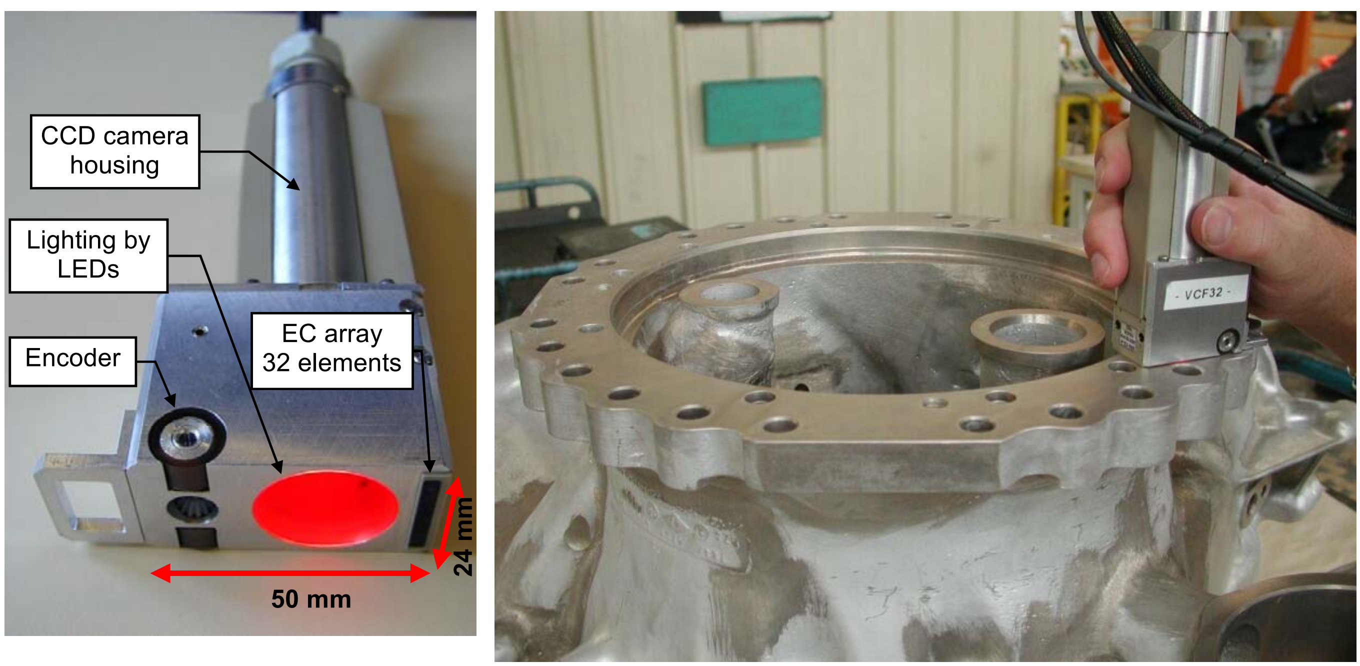

Figure 2: General view of the CODECI probe. Inspection of an helicopter gear housing with the probe.

Description of the EC probe: The EC array probe has been developed to detect surface breaking flaws with a minimum length of 1 mm and a minimum depth of 0.2 mm. It is made of 32 ferrite core coils assembled on two rows. The outer diameters of the coils is 1 mm and the spatial sampling of EC data is 0.5 mm in both directions. The EC coils are operated in the impedance mode in a Wheatstone bridge, with a reference coil within the probe used to balance the bridge. This operation mode was chosen to give an isotropic probe response regarding to the orientation of the flaw.

A specific multiplexer with 32 channels has been developed to command the set of coils. The multiplexing frequency ranges from a few Hz to 1 kHz, which leads to scan the coils at a maximum recurrence frequency of 30Hz. Considering a spatial sampling of 0.5 mm, the nominal speed of the probe is 15 mm/s.

The width of the inspected zone perpendicular to the displacement of the probe is 16 mm, and the multiplexing sequence is given in figure 3.

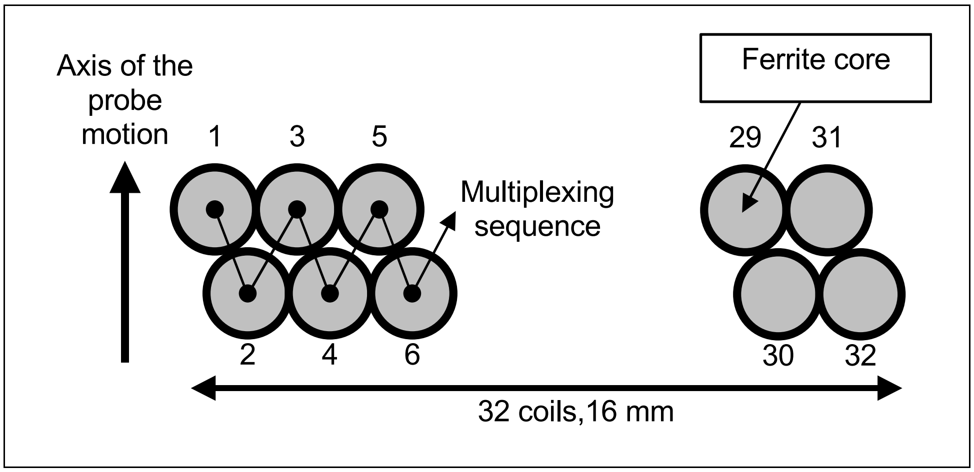

Figure 3: Eddy current array probe and multiplexing sequence.

Software architecture and flaw's characterization: Several processes are running simultaneously on the remote PC, mainly: digital image acquisition, digital image processing, EC acquisition detection, EC signal processing, overall characterization mixing the two techniques and real time display. The detection algorithm for both vision and EC is based on a threshold value and produces binary images for both techniques. The digital image processing gives the location, extension and width of flaws, whereas the EC data processing gives the amplitude and phase of the EC signals. The combination of the vision and EC techniques presents two major interests: first, the comparison between both images allows to exclude artefacts such as scratches. Second, data collected from the both techniques are analysed simultaneously to enhance the real-time characterization of small surface breaking flaws: knowing the length of the flaws by vision, their depths are evaluated from the EC amplitude by comparison to simulated signals in a look-up table.

The flaw's characterization method relies on the measurement of the maximum of the impedance variation as the probe scans the flaw. Given the length of the flaw at the surface from optical measurement, the depth is evaluated by comparison to simulated signals stored in a look-up table. In figure 4, the impedance variation is computed and plotted against the depth for various lengths of rectangular notches. The figure shows the drastic and well-known influence of the flaw length upon the impedance variation. It can be noticed that, even for a coil with an outer diameter of 1 mm, the impedance variation for a given depth is significantly modified when the length of the flaw varies from 1 mm to 4 mm.

The length of the flaws could also be estimated from EC signal but the resolution and bandwidth of the CCD camera are clearly many times better than the one reasonably achievable with the EC array probe.

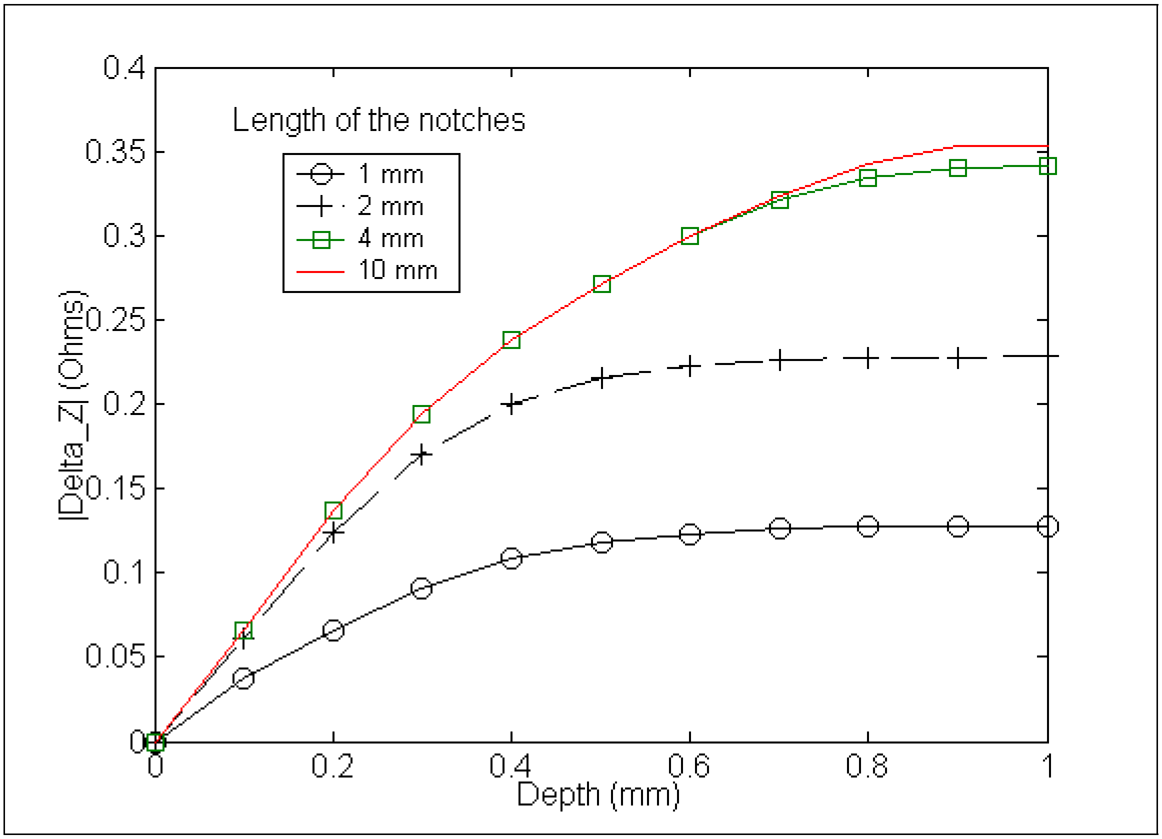

Figure 4: Maximum of the variation of the coil impedance for a rectangular EDM notch.
The test frequency is 300 kHz and the material is aluminum.
The notches have a width of 0.2mm, a length of {1, 2, 4 , 10 mm} and a depth ranging from 0.1 to 1 mm.

Results: The CODECI system has been evaluated on various alloys used in the aerospace industry such as aluminium, titanium and magnesium based alloys. The probe is scanned manually over the work specimen. An example of the system output is given in figure 5 for notches of 1 mm length and of various depth on a work specimen of aluminium alloy: the detection is good, and the accuracy of the depth evaluation is about 0.2 mm.

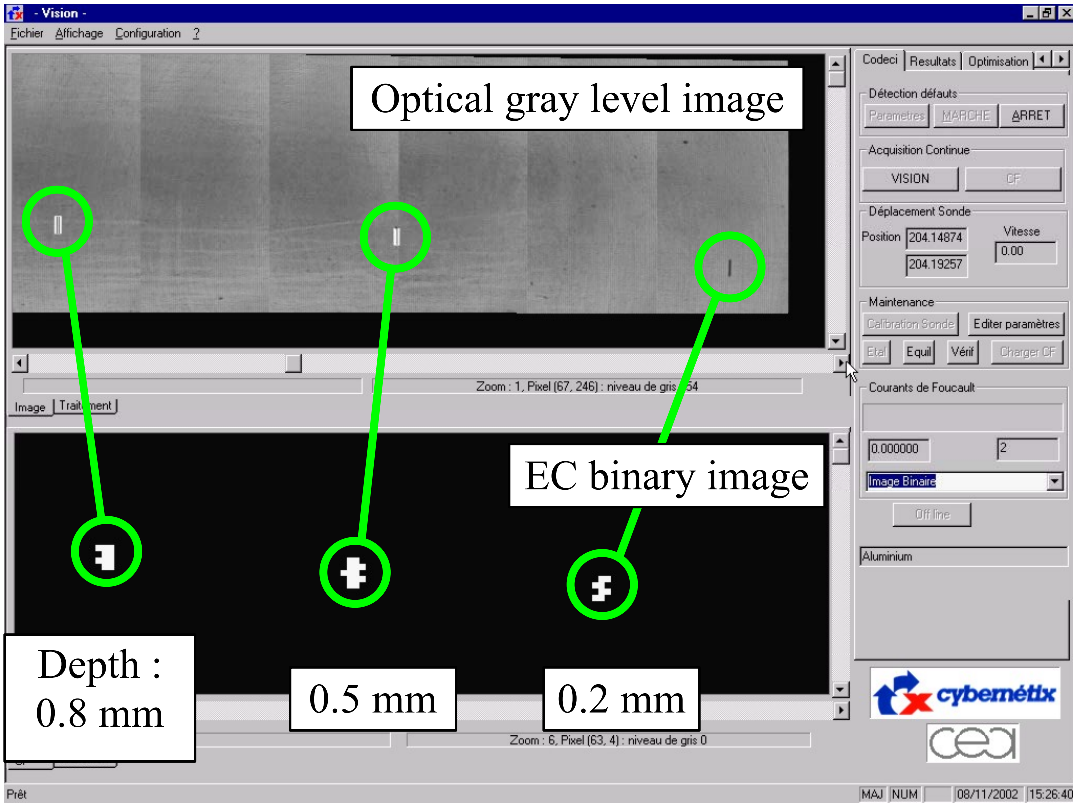

Figure 5: Detection and characterization of notches of 1 mm long in an aluminium slab.

Conclusions and perspectives: The system has demonstrated capabilities on planar or weakly curved surfaces. The sizing accuracy is approximately 100 µm for the length and 0.2 mm for the depth of the flaws. This system needs today further developments to address curved geometries for the work specimen, and complex inspection configuration such as network of cracks. The presented example shows the interest of the EC simulation tools to optimise the array probe design, and to enhance the characterization (length, width, depth) of the flaws.

References:

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[3] Sollier, T., Lorecki, B., Goupillon, O., "CODECI, a new system for the inspection of surface breaking flaws based on eddy current array probe and high resolution CCD camera", in ENDE'2003 Workshop Proceedings, IOS Press, 2004, pp. 215-222.