

# Virtual Instrument to Detect Defects in Conductive Materials

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**Abstract** — This paper describes a virtual instrument developed at the Instituto de Telecomunicações - Measurement and Instrumentation Group, to detect defects in conductive plates using eddy current methods. The measuring system allows the use of different types of probes which enable the determination of different magnetic field components and reconstruction of distinct images of the scanned sample under test.

## I. INTRODUCTION

In order to detect and characterize cracks and other defects in conductive specimens, several techniques based on eddy currents theory can be used [1-4]. In most of them the eddy currents are induced in the specimen under test by a magnetic field produced by an excitation coil carrying a time-varying current. These loop currents are proportional to the conductivity distribution and create a secondary magnetic field that contains the information about the defects in the specimen. Different detectors can be used to access the magnetic field.

This paper describes a virtual instrument that has been implemented at Instituto de Telecomunicações, Instrumentation and Measurement Group to automatically perform eddy current testing in metallic plates [5, 6].

## II. EXPERIMENTAL SETUP

### A. Block Diagram

Fig. 1 presents the block diagram of the implemented automated measuring system.

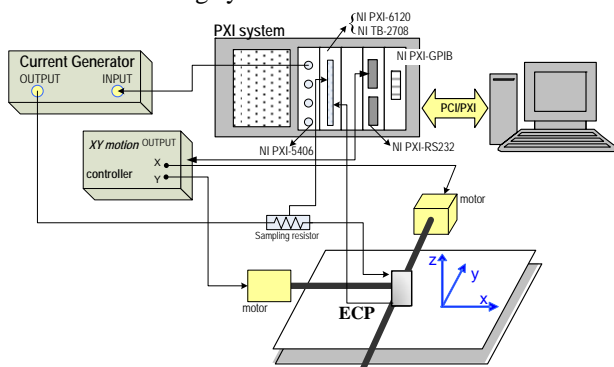


Fig.1. Block diagram of the implemented system.

The eddy current probe (ECP) scans the metallic plate under test using a XY-positioning system that works under a motion control device provided with a RS-232 interface. The magnetic fields generated are measured using a multifunction data acquisition module NI PXI-6120 included in a PXI-1036 6-slot chassis controlled remotely by a PC [7]. This board has four 16-bit, simultaneously sampled, analog input channels, with a maximum sampling rate of 1 MS/s per channel and 8 input ranges from  $\pm 200$  mV to  $\pm 43$  V. The function generator, NI PXI-5406, followed by a voltage to current converter, that delivers the necessary current to the excitation coil, is also included in the PXI system. This module as a built-in sine wave generation up to 40 MHz with 0.355  $\mu$ Hz frequency resolution and capable of 10 Vpp into a 50  $\Omega$  load. The RS-232 interface of the motion control device is provided by one of the two serial ports included in the NI PXI-8430/2 module. This module, with baud rates from 57 b/s to 1,0000 kb/s, has 128 byte transmit and receive FIFOs and memory mapping to prevent I/O resource conflicts.

Fig. 2 depicts a photograph of the described system. Two power supplies are used to power any conditioning circuit that might be included to adapt the sensor probe output.

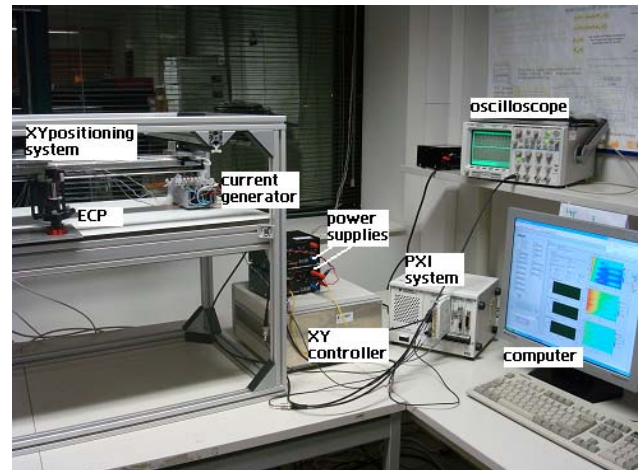


Fig. 2. Photo of the measuring system.

### B. Probes

Different types of probes can be used with the implemented measuring system.

They can be divided into two main groups according to the sensor unit used to measure the total magnetic field near the specimen. Either sensing coils can be used to access the e.m.f. due to time varying magnetic fields [8] or magnetic field sensors like giant magnetoresistors [9], anisotropic magnetoresistors, SQUIDS or Hall sensors.

Fig. 3 shows some that have been projected and built at our laboratory. As depicted in all the probes implemented the excitation coil is wound around a non magnetic and non conductive acrylic material.

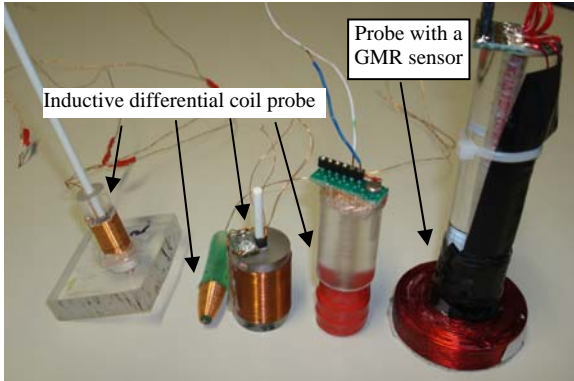


Fig. 3. Photo of some of the implemented probes.

### III. SYSTEM SOFTWARE

The application to control the automated measuring system was developed in a PC with the graphical programming language LabVIEW [10].

The program includes several components: to control the XY-positioning system; to excite the system and acquire data; to process digitally the raw data; to present the results.

The front panel of the implemented application is shown in Fig. 4. “*Tab Controls*” were used to separate the referred components: “*Comm. Config*” and “*Motion Config*” to specify the port used to communicate and to control the XY-positioning system; “*Meas*” to excite the probe, to acquire the data and to process digitally the raw data; “*EddyImage*” and “*Waveforms*” to present the results.

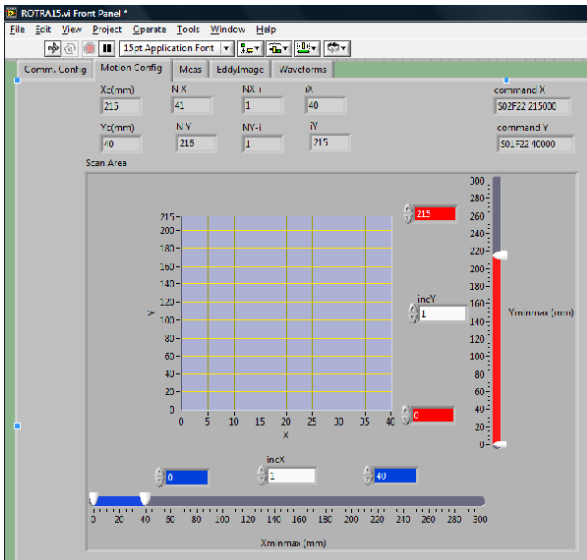


Fig. 4. Front panel of the tab pane “*Motion Control*”.

Fig. 5 presents the flowchart of the application developed. At the beginning it is necessary to specify the port that interfaces the XY-motion controller. Then the

scanned area must be characterized and the probe set at the initial position. The instruments are configured and each run allows the user to choose a list of test frequencies. Thus, at each position of the probe measurements are taken for all the specified frequencies and only afterwards the probe is moved to the next position.

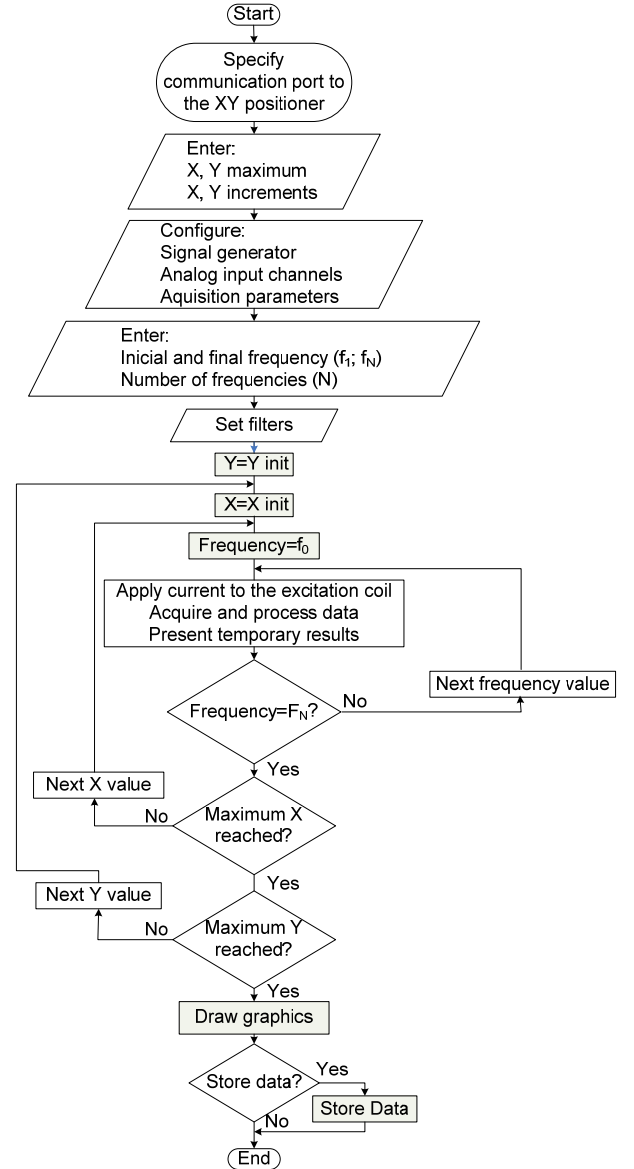


Fig. 5. Flowchart of the implemented application.

#### A. Motion Control

Fig. 4 presents the “*Motion Config*” tab control pane. The user must set the area to be scanned by the probe specifying the maximum values for the X and Y course and the desired increments in each direction. The user must guarantee that the probe is located at the initial position. The other displays shown are calculated by the program: total number of points, current position, number of remaining points, command sent to control the XY-positioner.

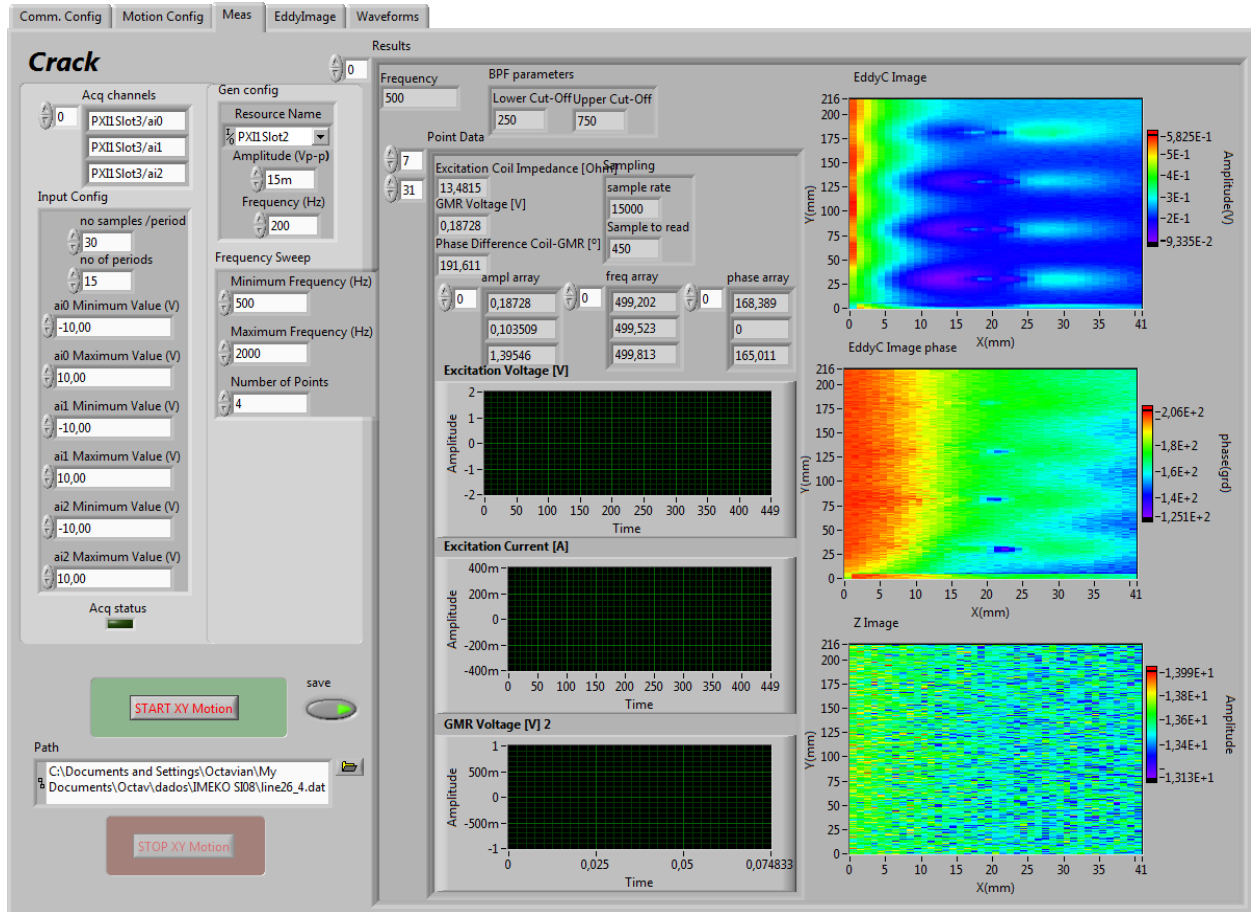


Fig. 6. “Meas” tab pane.

### B. Measurement

Fig. 6 presents the “Meas” tab control pane. On the left side of the pane are the controls to configure the parameters to run the measurement procedure. The results are presented on the right side.

Before starting the measurements the amplitude of the voltage generated by the function generator and the acquisition parameters (number of samples per period and number of periods) are specified. The sampling rate is set previously to a constant value (usually the maximum rate).

Another parameter that must be specified is the frequency. As represented in the flowchart (Fig. 5), this program allows, in one run, to test the specimen at different excitation frequencies. The initial and the ultimate frequency values and the total number of frequencies being swept must be set.

After all the parameters set the button “START XY Motion” must be pushed by the user to initiate the measurement. At each probe position one of the analogue input channels of the DAQ board measures the voltage at a sampling resistor and another the output (or outputs) of the probe during the number of periods previously specified.

The pane depicts the waveforms that are being obtained, the eddy images that are being built and the data arrays.

### C. Data Processing

There is some digital signal processing to improve signal resolution [11]. Thus, after filtering the raw data by a numerical low-pass filter to remove the white noise (with null mean value) and by a Butterworth filter with the lower and upper cut-off frequencies specified by the user, the amplitude and phase of the probe output voltage must be computed. This is done using the “Tone Measurements Express” VI, which comes with the “Full Development System” of LabVIEW, is able to estimate the sine wave amplitude, initial phase and frequency. This VI is also used for the other channels to estimate the amplitude and initial phase of the excitation voltage and excitation current. With these parameters, the excitation coil impedance and the phase difference between excitation current and sensor voltage are computed (Fig. 7).

### D. Data Store

In order to store the measured quantities, the user is asked to push a button and to confirm the name of the file to contain the data.

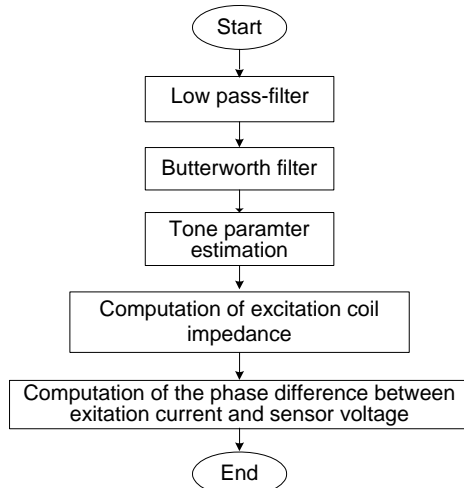


Fig. 7. Signal processing flowchart.

### E. Results Presentation

Fig. 8 represents the “EddyImage” pane. The images shown depict the result obtained for an aluminum plate with four holes artificially made. Other types of presentation can be set.

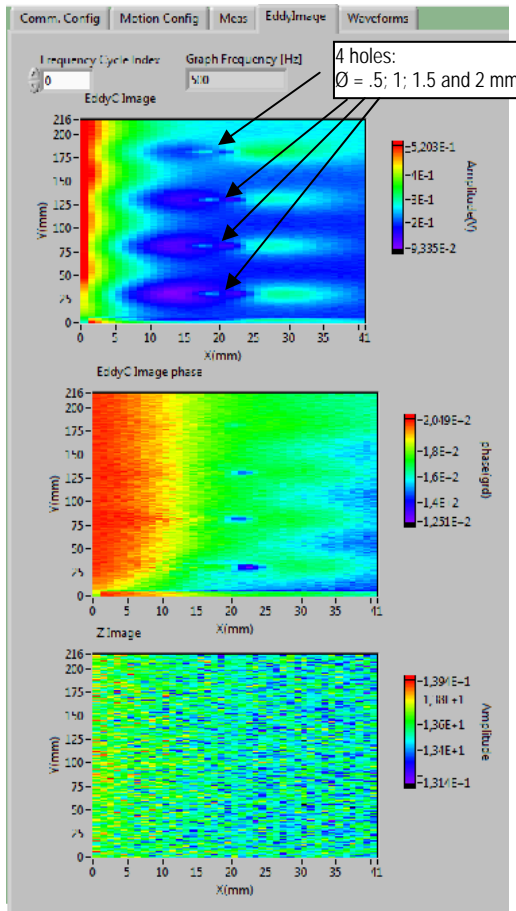


Fig. 8. “TestImage” pane.

## IV. CONCLUSION

This paper presented the virtual instrument created to assist in the scientific research of eddy current based methods of defect characterization in metallic materials. It automates all the process, from signal generation, measurement and processing to probe positioning. This system allows efficient use of the researcher time as well as guaranteeing an high reproducibility of results.

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