The eddy current inspection method
Part 3. Instrumentation and applications

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Basic instrumentation
There are a number of basic groups of eddy current instrumentation.

These may be categorised as:
- Meter display instruments
- Portable impedance plane instruments
- Tube testing instruments
- Array Systems
- Automation systems
- Measuring equipment

Although it is easy to categorise instrumentation the boundaries are typically very fuzzy.

Meter display instruments
Simple easy-to-use equipment, operating at a restricted number of fixed frequencies – typically several hundred kHz – with a meter or bar-graph display. Only suitable for surface crack detection and simple sorting applications.

The controls are usually restricted to a gain control (a potentiometer) for sensitivity adjustment, coarse frequency selection switch, material selection switch and a balance control pushbutton.

The balance control normally gives some means of compensating for lift-off (for example phase rotation and/or fine frequency adjustment) so that the meter is most sensitive to crack-like indications. An alarm threshold is usually included to provide audible and visual output that an indication has occurred.

The information presented to the operator is, by definition, extremely simple. The use of mechanical meters means that response to defects is very slow as the meter requires time to respond to rapid changes.

Typical frequencies used are:
- 200 to 500 kHz for general purpose crack detection
- 2 MHz for detection of small (0.1 mm deep) cracks in aluminium
- 6 MHz for crack detection in low conductivity materials particularly titanium.

This type of instrument has now been almost entirely superseded by impedance plane instruments.

Portable impedance plane eddy current flaw detectors
The availability of low cost graphic displays and improvements in battery technology has meant the widespread availability of cost-effective low weight battery-operated digital impedance plane instruments.

Such instruments give a real impedance plane display on a CRT (see Figure 20) or, now more commonly, electronic display (LCD, electroluminescent, etc). Generally these have comprehensive capabilities: wide frequency ranges from around a hundred Hertz to several mega-Hertz, extensive alarm facilities, general purpose units may have signal filtering. It is now common for instruments to offer dual frequency operation, allowing the combination of signals at two or more test frequencies (termed mixing) in order to reduce or eliminate specific interfering effects.

Low current consumption displays and higher energy density batteries have led to extremely portable units with long battery lives. At first battery operation for this type of instrument was by using nickel cadmium (NiCd) batteries. NiCd suffers from the memory effect, which is problematic in the typical inspection industry usage patterns. Modern Lithium Ion (Li-Ion) batteries have no memory effect and much greater charge for weight density. The charging is necessarily more complex but brings advantages in rapid charging and no disadvantage in top-up charging.

Microprocessor control has enabled easy use through menus and user-definable softkeys with internal storage of settings and test data. Connection of instruments to a PC gives the ability to: back-up settings and test results, copy information to other PC applications (for example word processor or database) and transfer of inspection procedures from one instrument to another.

These features are contained in an ergonomic case weighing under 1 kg including the battery.

Typical applications include surface inspection, but now the impedance plane display adds the ability to perform more complex inspections, such as weld inspection, whereas the frequency range, which can be as low as 10 Hz, enables corrosion and sub surface defect inspection to be performed.

At the top end of the range for this type of equipment, manufacturers add the capability to measure electrical conductivity on non-magnetic material and support for rotary drives. Rotary
drives enable rapid and reliable inspection of holes (rotating at up to 3000 rpm). The main application for this equipment is in in-service inspection of aircraft. Such instruments provide the three major applications for eddy current in aircraft inspection all in one convenient package. A rotary system, apart from requiring the capability to drive the motor in the drive, also must have high and low pass signal filters that can be set extremely precisely to optimise the signal to noise ratio and thus enable the reliable detection of extremely small defects.

**Tube testing instruments**

These are used almost exclusively to test heat exchanger tubing with internal diameter probes. Typical equipment will test simultaneously at four frequencies using differential bobbin probes. As a differential test is only sensitive to short defects, then the test is repeated in absolute mode for all frequencies.

Figure 21 shows a typical response obtained in the differential mode. By testing at four suitably chosen frequencies, signals from ferrous support plates, ferrous inclusions and dents may be suppressed whilst defects may be characterised such as corrosion pitting and cracks. This method is widely used because of the speed of test (1 to 2 m/s), ability to automate (for instance in remote pressurised water reactor steam generator inspection) and lack of any other NDT technique that offers any significant advantages. Vast amounts of data are produced leading to problems with data handling and reliable analysis. Computerised analysis is the answer but not widely used at present.

**Array systems**

An array system tests simultaneously with numerous identical eddy current probe elements, for practical reasons varying in size from 8 to 128 elements. The advantage is that instead of scanning the probe mechanically over a surface, multiple elements uniformly spaced scan one width of the surface giving near equal sensitivity over a surface profile. The elements are electronically scanned (multiplexed). One disadvantage is cost because the probe and its associated electronics are necessarily complex; if the component shape or size changes then a new probe is required and currently the element size means that the transverse resolution is very coarse when compared with a conventional mechanical scan. This means that inspection is usually carried out on high value components such as aircraft engine disk inspection.

**Industrial automation systems**

Eddy current inspection provides a simple way of inspecting components for surface-breaking defects. High surface scanning speed, typically two metres per second, coupled with non-contacting probes means that rotationally symmetrical components (such as bearings, bolts, ball joints, cylinder liners, gudgeon pins, clutch plates, wheel axles etc.) may be inspected during the manufacturing process.

These are intended for factory operation, often in automatic or semi-automatic inspection machines. Generally, they are similar in operation to impedance plane portables but usually have extensive input and output facilities such as relays and photocell inputs. Emphasis is not on low power consumption, portability and weight. The capability to mount the equipment in an industrial environment is important. The systems may be custom built for a specific purpose, in which case features not needed for the intended application are often omitted.

**Figure 21. ID probe and typical impedance plane traces from a calibration standard**

Remote field inspection is a method developed for inspecting carbon steel tubes from the inner diameter. The probe is a transmit receive probe with the driver and receiver spaced approximately three diameters apart. Over this distance, the near field is attenuated and a field that takes a path through the tube thickness along the outer surface and then returns to the bore. Signal amplitude is related to defect volume and phase to depth (as in conventional eddy current inspection), however there is no discrimination between internal and external defects. As carbon, steel tubes typically become heavily corroded during use and still be within their design tolerances it is not practical to detect small defects due to the high background noise levels.

**Figure 22. Automated system for aircraft wheel inspection**

One example of a standard system is for aircraft wheel half inspection (see Figure 22). Aircraft wheels are subject to high stresses during landing and take-off, and are inspected at each tyre change or heavy landing. Wheel halves are coated to prevent corrosion and not having to remove this coating to inspect is a major cost saving. With an automated system, an inspection can take as little as 30 seconds to inspect over a path length of 250 m. The probe used is an absolute probe. Data presentation is in the form of a chart record showing a defect channel and a lift-off/signal coupling channel.

A bar-code scanner is used to automate test set-up selection and all data may be stored to a local hard disk. A chart recorder is included to provide a paper test result. Test reporting may also be paperless and the system attached to a network giving the ability to view test results remotely. This unit uses a standard hand held conductivity meter.
eddy current impedance plane instrument that may be detached for use in manual inspection.

Eddy current systems may also be used for determining heat treatment status of metals using a comparative test.

Special-purpose measuring equipment
A number of instruments use the eddy current principle to provide actual numeric data, examples are:
- Coating thickness meters
- Conductivity meters (AutoSigma 3000).
- AC field crack depth meters
- AC field stress measurement

Generally these are designed to give a digital readout without demanding interpretation of an indication (see Figure 23). Conductivity meters find applications during metal manufacturing for quality control of non-ferrous alloys and heat treatment and in service for heat damage assessment.

Next month’s concluding article in this series will discuss applications, considerations in setting up an instrument and a bibliography.