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**THE PHOTOTHERMAL CAMERA METHOD
TECHNOLOGY UPDATE AND RECENT RESULTS**

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Abstract

The Photothermal Camera, developed by AREVA NP in collaboration with ONERA, is an inspection instrument that can be used to replace more conventional surface inspection techniques such as ET or PT.

Photothermal testing is a contactless NDT technique that detects infrared emission following a transient thermal excitation of the inspection target. An infrared sensor is combined with a scanning laser excitation source to comprise the Photothermal Camera. The focused laser scanning beam almost instantly heats a line on the target surface to be inspected. The infrared detector measures the IR emission of the surface adjacent to the heated area as the thermal wave propagates away from the line of initiation. On-line analysis of the image enables the cracks, acting as a thermal barrier, to be clearly shown by their characteristic flaw footprint.

The Photothermal Camera avoids direct contact with inspection areas by the operator. No chemicals are required for the process. Photothermal inspections generate no environmental waste in contrast to alternative surface inspection like Liquid Penetrant or Magnetoscopy Testing. The method is also relatively quick and therefore the operator exposure to hazards of the general inspection area may be minimized. Thus the method is ideal for situations where surface contact can be hazardous to the operators (like contaminated nuclear components) or materials and environments that may be sensitive to chemical exposures.

This paper will present the principle of this technique coupled with example results from recent applications obtained from EDF's mock-ups. Most notable will be results for depth sizing of open cracks in the range of 0 - 3 millimetres where the ultrasonic methods are limited.

INTRODUCTION

AREVA is a nuclear energy company committed to producing and distributing CO₂-free energy in innovative ways that are cleaner, safer and more economical. The *Photothermal Camera* is an example of this innovation allowing contactless non-destructive tests of surface defects. The equipment (figure 1) and physical process (figure 2) were developed in partnership with the French aerospace design and research bureau, ONERA. Decades after the advent of the more conventional industrial inspection techniques (such as X-ray, penetrant, magnetic particle, ultrasound and eddy current inspection), this scientific and industrial development project led to new a NDT technology that protects the environment and worker health. This paper presents the principle of this technology coupled with example results from recent applications obtained from EDF's mock-ups.

PRINCIPLE

Photothermal testing is a contactless NDT technique that detects infrared emissions following a transient thermal excitation of the inspection target. An infrared sensor is combined with a scanning laser excitation source to comprise the Photothermal Camera. The focused laser scanning beam almost instantly heats a line on the target surface to be inspected. The infrared detector measures the IR emission of the surface adjacent to the heated area as the thermal wave propagates away from the line of initiation. On-line analysis of the image enables the cracks, acting as a thermal barrier, to be clearly shown by their characteristic flaw signature.

The Photothermal Camera avoids direct contact with inspection areas by the operator. No chemicals are required for the process. Photothermal inspections generate no environmental waste in contrast to alternative surface inspections like Liquid Penetrant or Magnetoscopy Testing. The method is also relatively quick and therefore the operator exposure to hazards of the general inspection area may be minimized. Thus the method is ideal for situations where surface contact can be hazardous to the operators (like contaminated nuclear components) or materials and environments that may be sensitive to chemical exposures.

The *Photothermal Camera*, and its acquisition and analysis applications

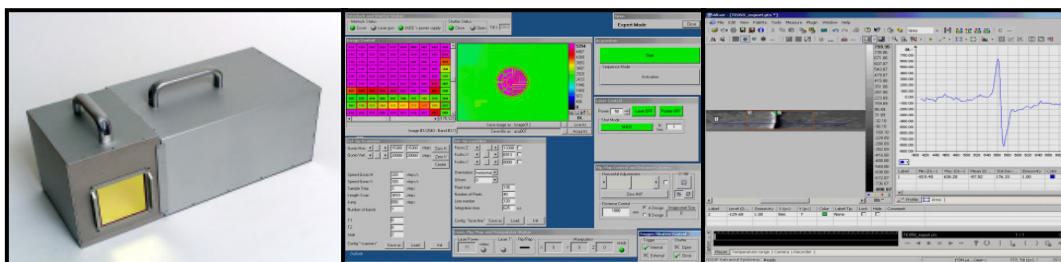


Figure 1

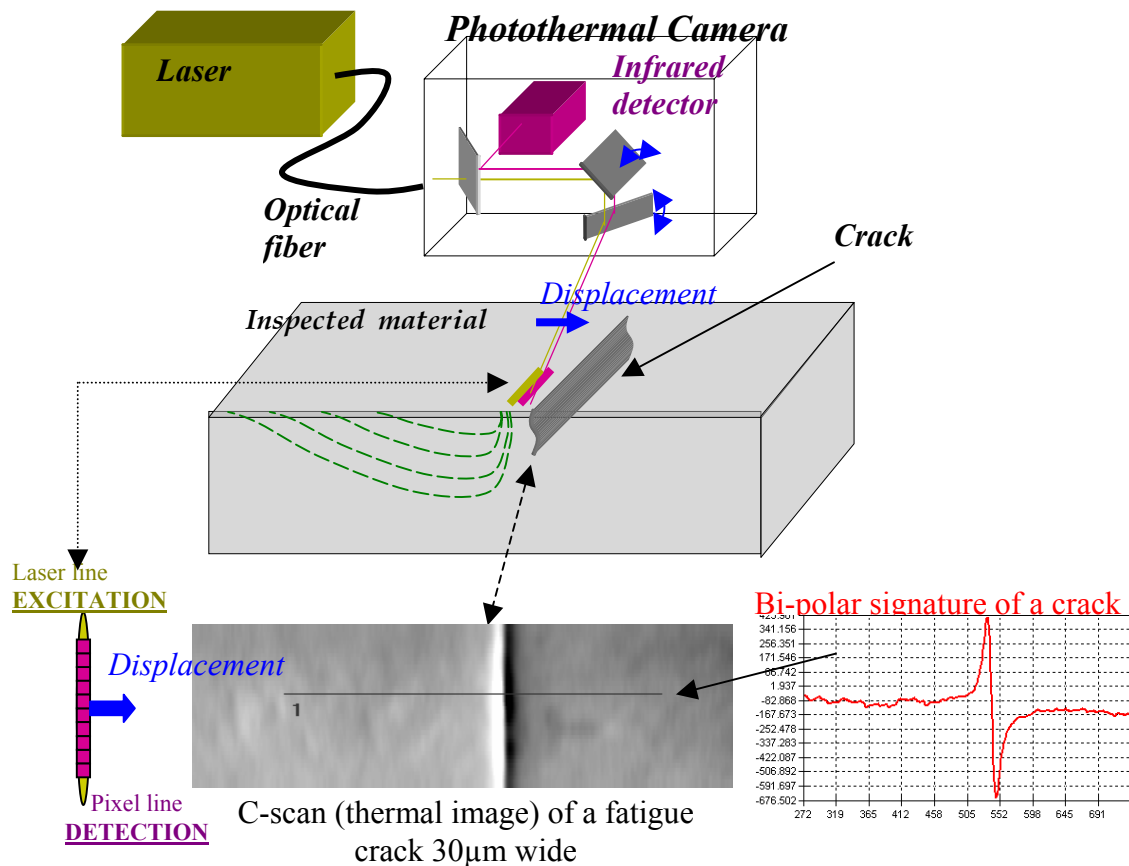


Figure 2

COMPARISON BETWEEN THE PHOTOTHERMAL CAMERA AND PENETRANT METHOD

A comparison between the *photothermal* process and the conventional penetrant method was carried out on a tubular test piece whose inner surface contained crazed cracks. This confirmed that the sensitivity of the *photothermal* process was capable of locating the cracks with no particular difficulty. The focus range of the optical device was also able to accommodate the defocusing caused by scanning the inner surface studied.

This test case did not require any particular adaptation of either the optical device or the actual measurement (image acquisition, processing and view). The results of the *photothermal* and *penetrant* methods are shown in figures 3a and 3b (EDF's mock-up).

While both methods produced similar information, the digital data provided by the *photothermal* process is advantageous in that it can be stored and processed (for improvement, quantification and classification). This characteristic is appealing as it allows observations to be reproduced, and the data to be fully utilized (e.g. traced and compared to previous states) to monitor the developments of discontinuities, both over time and space.

Figure 3a: Photothermal image of the tubular test piece

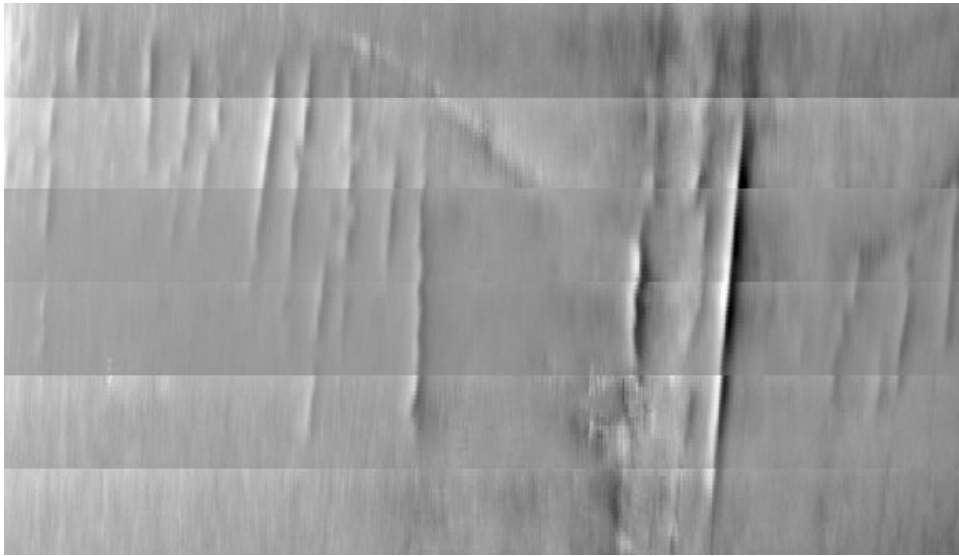
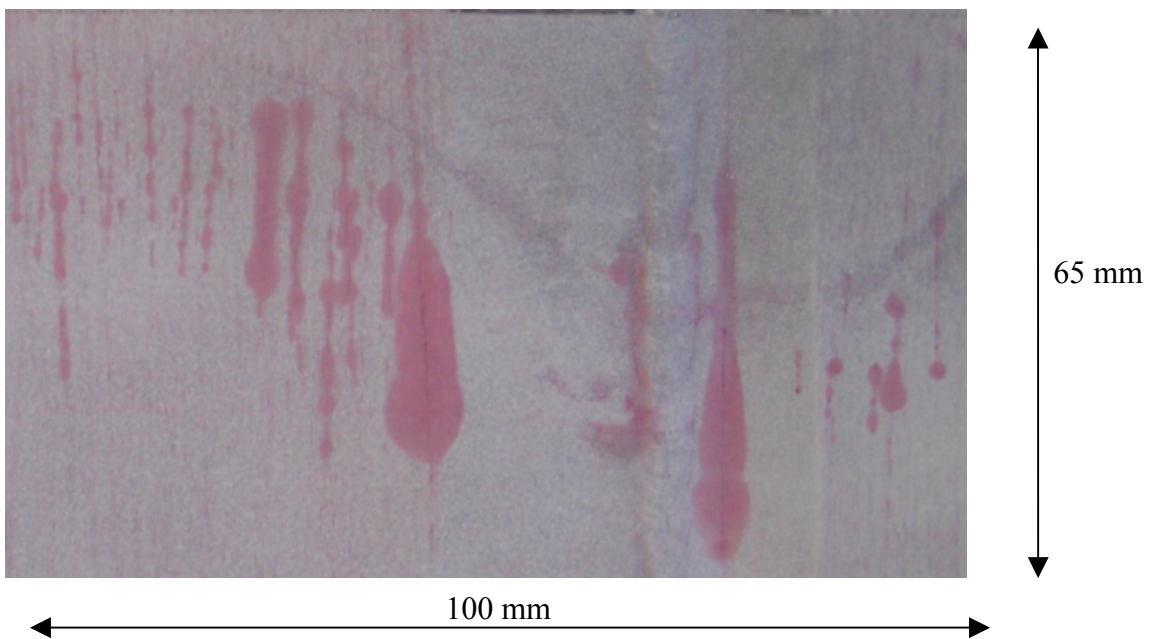


Figure 3b: Penetrant image of the tubular test piece



Comparison of the indications from both methods
show equivalent results on this EDF's mock-up with thermal crackling

DEPTH SIZING OF CRACKS

There is a relationship between the peak to peak bipolar crack signal amplitude and the depth of the cracks (figure 4). For that we made some coupons with fatigue cracks with various depths in the range of 0.2 to 3 mm:

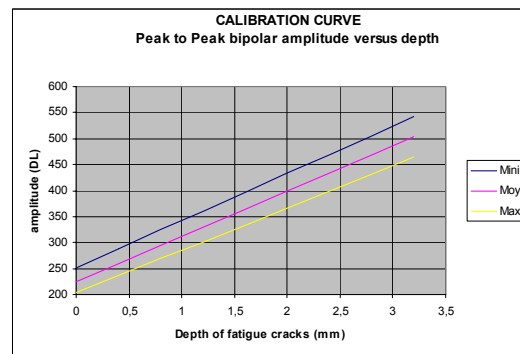


Figure 4: mock-ups with calibrated depth cracks and the associated calibration curves

The photothermal method was then tested on the EDF's mock-up, PP/AP06, with two known depth flaws (figure 5).

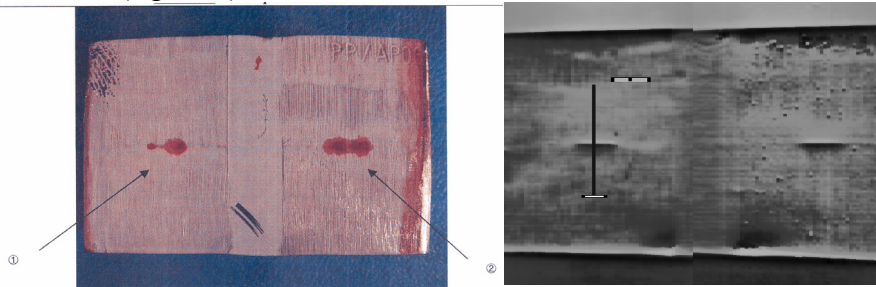


Figure 5: mock-up PP/AP06 – Liquid Penetrant and Photothermal testing

Then, the Peak-to-Peak amplitude (in Digital Level) of each flaw was noted on the calibration curve, to predict the actual crack depth with the following results (figure 6):

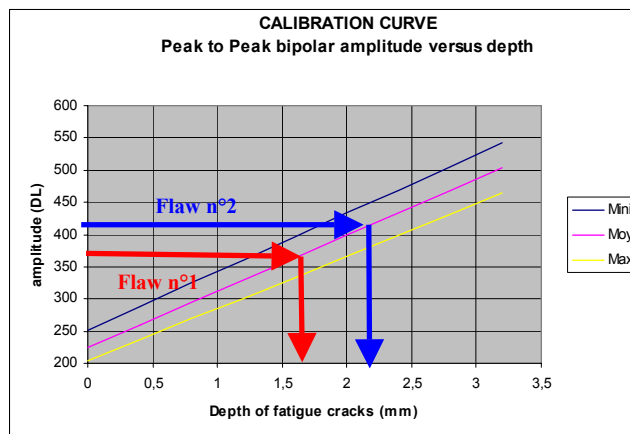


Figure 6: Peak-to-Peak amplitude of the two mock-up PP/AP06 flaw signals on the calibration curve

And with uncertainties considered:

- Flaw n°1: 1.7 +/- 0.4 mm (for 1.98 mm true depth by metrology)
- Flaw n°2: 2.2 +/- 0.4 mm (for 2 mm true depth by metrology)

Nevertheless, these results concerning the depth sizing have to be improved for a better confidence and measurement accuracy.

BENEFITS OF THE TECHNIQUE

The *Photothermal Camera* process and the penetrant method were shown to perform equally well (figure 3). As with penetrant inspection, the *Photothermal Camera* can be used to detect surface breaking cracks just a few microns wide:

- in metal parts with rough industrial surfaces (e.g. oxidized, machined or welded parts),
- at an inspection productivity rate of around 1 m²/ hour (for surface breaking cracks in stainless steel).

However, unlike the penetrant method:

- *Photothermal* inspections are performed:
 - without contact with the inspected part (measuring distance 0.1-2 m),
 - without the use of products that may be potentially hazardous for the operator or the environment,
 - with limited preparation of the test surfaces (dry and no dust),
 - without any operator-dependent procedure (e.g. extensive cleaning of the part before penetrant testing), as the entire inspection is automated,
 - without exposing the operator to the structures to be inspected (which may be hot or contaminated).
- The results of the inspections are stored digitally in as a series of images, ensuring the traceability of inspections. The images offer a direct view of the defects, which clearly appear on the thermal image of the inspected part.
- *Photothermal* inspections can also:
 - detect non surface breaking defects,
 - be performed on high-temperature parts (e.g. after welding) or porous materials.
- The *photothermal method* is suitable for depth sizing of open cracks in the range of 0 - 3 millimetres where the ultrasonic methods are limited.

Finally, the *Photothermal Camera* can be used in situations where other industrial surface inspection methods (namely eddy current and magnetic particle) are impossible. It can be used:

- on insulating (dielectric) materials, and
- without being adversely affected by the magnetic properties of the inspected material.

APPLICATIONS

Potential *Photothermal Camera* uses in industrial and nuclear sector include:

- Inspection of primary system components for power plants (reactor, steam generators and reactor coolant pipes).
- High temperature inspection surface (up to 250°C)
- Inspection of core components of the ITER reactor.

An agreement between EDF and AREVA is already underway to support this industrial development to establish guidelines for a standard addressing this technology.

The guideline scope included:

- performance verification,
- qualification including identification of critical parameters,
- operator certification,
- Standardization.

These actions are to be performed as part of and in addition to the aforementioned initial industrial applications.