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Development of an original active thermography method adapted to ITER plasma facing components control

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Abstract

Among all non-destructive examinations (NDE), active infrared thermography is becoming recognised as a technique available today for improving quality control of many materials and structures involved in heat transfer. The infrared thermography allows to characterise the joint between two materials. In order to increase the defect detection limit of the SATIR test bed, several possibilities have been evaluated. The implementation in 2003 of a microbolometer camera and the improving of the thermosignal process allowed to increase considerably the detection sensitivity of the SATIR facility. The quality, the spatial stability of infrared image and the detection of edge defect have been also improved. The coupling on the same test bed of SATIR method with a lock-in thermography will be assessed in this paper. An improvement of the global reliability is expected by data merging produced by the two thermal excitation sources. This new facility SATIR UPGRADE has been designed for the full non-destructive examination of the high heat flux (HHF) components taking into account these main improvements. These systematic acceptance tests obviously need tools for quality control of critical parts.

Keywords: SATIR facility; Lock-in thermography; Interface defect detection; Data merging

1. Introduction

The control of joints by infrared thermography is an original test, which is used as an acceptance tool by the Tokamak TORE SUPRA in order to guarantee joint quality of the high heat flux (HHF) components delivered by the manufacturer. SATIR method was developed, specially, by CEA in order to evaluate the manufacturing process quality of actively water-cooled plasma facing components such as toroidal pumped limiter (TPL) before their installation inside the TOKAMAK TORE SUPRA and has proved to be very efficient in terms of defect detection. The technical specifications for the supply of international thermonuclear experimental reactor (ITER) targets stated that all Cu cast layers on W or CFC armour should be

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subjected to 100% thermographic examination, such as the CEA developed SATIR test. The external active control method by lock-in thermography can also be considered in order to improve the CFC/Cu interface defects detection. Ultimately, the merging of the two techniques should improve the detection sensibility and reliability up to the point where accurate flaw shape can be detected. In parallel, an important effort of the infrared image processing improved the detection sensitivity of SATIR method. The control of Wendelstein-7X Divertor pre series components expected in 2005 shall validate these enhancements. The comparison of the infrared image processing results with the previous software has been performed and showed a very significant improvement. This paper proposes a detailed overview of improvements, which would equip this new infrared thermography test bed.

2. Improvement of SATIR image processing

This study was carried out on the CFC flat tiles component of 6 mm thickness manufactured with Active Metal Casting® process. These types of element were used to build the TPL (Huber et al. [1]) of TORE SUPRA. The SATIR facility was the subject of several papers (Durocher et al. [2]) and its principle will not be detailed completely here. In 2003, the implementation on SATIR test bed of a microbolometer digital camera SC500-FLIR (320 pixels × 240 pixels) using wavelengths range 8–12 μm instead of a scanning infrared camera INFRAMETRIX allowed to develop a new infrared image processing software.

2.1. Thermosignal normalisation

A new normalisation data processing by pixels clearly showed an improvement of the infrared image quality and the detection sensibility. Thus, another normalised infrared film was rebuilt taking into account the variation of emissivity and a constant water temperature. In this case, the thermal cycles at each stage have to be sufficiently long to apply the normalisation algorithm at constant temperature.

2.2. DTref value

This infrared image process requires some precautions, such as the time origin, t_0, of the pixel temperature evolution, which have to be considered to obtain coherent DTref value. A maximum DTref value cartography by pixel is built for the heating and cooling cycles from the new infrared film. DTref comparative measurement between the initial and the new process realised on TPL element showed an increase by factor of 2 of the sensibility defect detection as shown in Fig. 1. The using of the new infrared camera part brought 30% of the global improving.

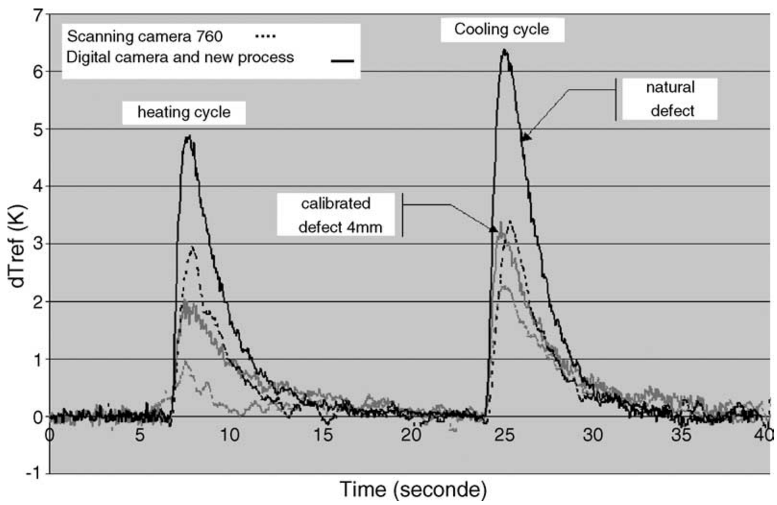

Fig. 1. Improvement of the defect detection sensibility.