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NONDESTRUCTIVE TESTING OF OBJECTS OF COMPLEX SHAPE USING INFRARED THERMOGRAPHY: DETERMINATION OF THE SPATIOTEMPORAL DISTRIBUTION OF THE IRRADIATION HEAT FLUX

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The existing inverse methods used to determine the heat flux density require that the forward problem and the problem domain (geometry) be known. In this paper, in order to determine the spatiotemporal heat flux density without knowing the real problem domain, we propose an approach based on temporal tracking of the thermal front. The proposed approach is particularly relevant when a three-dimensional formulation is adopted for nondestructive testing using infrared thermography. For such a formulation, heat flux density resulting from the external thermal stimulus is needed and must be determined to accurately characterize the defects and reconstruct the internal geometry of the inspected objects. The proposed approach uses only two inputs: the time-dependent temperature of the frontal surface recorded by an infrared camera and the 3D point cloud of the frontal surface collected by a 3D scanner. The method is evaluated numerically on an object of complex shape. We consider the case of pulsed thermal stimulus as well as the cases of unit step and modulated thermal stimuli. An experimental validation is performed on a cylindrical object submitted to a pulsed thermal stimulus and a modulated thermal stimulus. The results show the accuracy of the method which can easily be implemented as the initial step of the three-dimensional quantitative nondestructive testing of objects using infrared thermography.

Keywords: Heat flux density, infrared thermography, 3D scanner, 3D nondestructive testing, temporal tracking of the thermal front, inverse problems.

1. INTRODUCTION

Infrared thermography (IRT) is a promising technique for quantitative nondestructive testing (NDT) of objects based on their thermal behavior [1]. Compared to other established methods used for NDT, infrared thermography has the advantage of allowing contactless data acquisition and whole field measurement through the use of an IR camera. In active IRT, the inspected object is heated/cooled using an external thermal stimulus and its temperature is analyzed to quantify its subsurface degradation state. Almost all studies addressing quantitative NDT using IRT base their theoretical analysis on the one-dimensional thermal model and thus impose that, for the sake of accuracy, a uniform heating is required during the experiments [1-2]. This reduction of the problem to one dimension restricts applications to objects with trivial and regular geometry such as planes. Moreover, it sacrifices accuracy when the thermal stimulus is not uniform and/ or the inspected object shows one or more of the following features: complex shape; high thermal diffusivity; defects with nontrivial geometry. The ability to deal with objects of complex shape and high thermal diffusivity and to operate without any constraint of uniformity of heating/cooling as well as the improvement

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