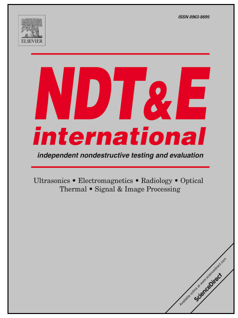

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Detection and reconstruction of complex structural cracking patterns with electrical imaging

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Abstract

The ability to detect cracks in structural elements is an integral component in the assessment of structural heath and integrity. Recently, Electrical Resistance Tomography (ERT) -based *sensing skins* have been shown to reliably image progressive surface damage on structural members. However, so far the approach has only been tested in cases of relatively simple crack patterns. Because the spatial resolution of ERT is generally low, it is an open question whether the ERT-based sensing skins are able to image complex structural cracking patterns. In this paper, we test the accuracy of ERT for reconstructing cracking patterns experimentally and computationally. In the computational study, we use a set of numerical simulations that model progressive cracking in a rectangular beam geometry. We also investigate the effect of image reconstruction methods on the crack pattern estimates: In addition to the contemporary image reconstruction method used in the recent sensing skin studies, we test the feasibility of a novel approach where model-based structural prior information on the cracking probability is accounted for in the image reconstruction. The results of this study indicate that ERT-based sensing skins are able to detect and reconstruct complex structural cracking patterns, especially when structural prior information is utilized in the image reconstruction.

Keywords: Damage Detection, Finite Element Analysis, Image Analysis, Inverse Problem

1. Introduction

The detection of damage in structures is paramount in the assessment of safety, functionality, and serviceability of structures. In practice, numerous processes may contribute to progressive structural damage. Broadly speaking, these contributors may include cracking of reinforced concrete, corrosion of metallic structural members, localized damage due to impact, fatigue, fracture, excessive plastic deformation, and much more [1, 2, 3, 4].

Some popular methods used for detecting local and/or distributed damage utilize optical [5], image-correlating [6], ultrasonic [7, 8], capacitive [9, 10], or direct-strain [11] modalities. Recently, the use of electrically-conductive sensing skins coupled with Electrical Resistance Tomography (ERT) for imaging spatially-distributed damage has been a source of much research interest [12, 13, 14, 15, 16, 17]. In related works, the use of ERT to monitor moisture flow in cement-based materials, a significant contributer to environmental degradation, in two- and three-dimensions was shown in [18, 19, 20, 21]. In [22], the ERT-based sensing skin was shown to be feasible for detecting corrosive agents on the concrete surface. In [23], ERT was used to detect carbonation in cement-based materials.

In ERT, surface measurements are taken and images of the electrical conductivity distribution are reconstructed by numerically solving the ERT inverse problem. The attractiveness of ERT is often centered around the low monetary cost, minimal space requirements, and rapidity of measurements. Some disadvantages of ERT are the sensitivity to measurement noise and modeling errors [24, 25] and the high-computational cost when using fine meshes with iterative minimization regimes [26, 27]. On the other hand, the computational

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