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Editorial

Advanced Numerical Approaches for Crack Growth Simulation

Roberto Citarella * **and Venanzio Giannella**

Department of Industrial Engineering, University of Salerno, 84084 Fisciano, Italy
* Correspondence: rcitarella@unisa.it

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1. Introduction

The purpose of this Special Issue was to highlight the latest developments in the usage of advanced numerical approaches for crack growth simulation. In proposing this wide topic, we wanted to provide engineers and researchers with the chance to publish their current studies, both in the experimental and theoretical fields of fracture mechanics, crack propagation, and residual life assessments, which can be of interest not only for performing a structural integrity assessment with a high accuracy but also for achieving a better comprehension on the mechanism of failure. This issue provides an overview of several articles surrounding the abovementioned subjects.

In the following, a brief summary on the content of the papers included in this Special Issue will be presented.

2. The Present Issue

This Special Issue attempted to gather the latest research on the numerical approaches for the simulation of fracture problems, a very hot topic in research at the present time [1–3]. Particularly, this SI focused on simulations for both traditional (e.g., metal materials) and innovative materials (e.g., composites or additively manufactured) through the usage of different numerical approaches. When possible, the papers highlighted not only the enhanced accuracy but also the computational time efficiency.

The propagation of cracks and defects in structures depends on the cyclic loads applied on it, such as mechanical, thermal, residual stresses, etc. This highlights the need to account for all kinds of loading conditions in simulating the fracture problem. In [4], for the first time, Adapcrack3D has been adopted to simulate three-dimensional problems by considering cyclic mechanical loads and static thermal loads. Adapcrack3D was updated to work with FE models comprising multiple parts and relevant features such as coupling and surface interactions. Additionally, Adapcrack3D used the submodel technique for the fracture mechanics assessments, comprising the architecture of the submodel modified to simulate models with contacts defined between the crack faces. The software was tested with different 3D models and the results were in a good agreement with the experimental and numerical reference data. The results confirmed that the simulation of contacts in Adapcrack3D was a major step in improving the functionality of the program. Various practical application areas were also highlighted, in which this newly implemented feature in Adapcrack3D can be applied, e.g., fatigue crack growth in gears, bearings, rolling contact fatigue in rails, etc.

When referring to the propagation of cracks in vessels and pipelines, leaks and ruptures may result in substantial environmental consequences and income losses for the oil and gas industry. To reduce the failure probability and at the same time to retain the system's design capacity, the technical conditions of pipelines have to be periodically controlled by in-line inspections, which are scheduled in order to detect potential damages or defects that can endanger the system's loading capacity. In [5], a numerical–experimental study has been performed for a composite-repaired pipeline made of API 5L X60 steel. An experimental burst test was carried out on a 4 m long pipe section and tested up to the complete failure. The test was simulated numerically by means of an FEM model of the composite-repaired steel tank in such a way to allow for a cross-comparison of the outcomes. It was found that the investigated composite repairing technique eliminated almost the whole noteworthy thickness reduction of nearly 80% and the related stress concentrations in the pipe.

Similarly to oil and gas, the aircraft industry has required in recent decades the accurate prediction of the propagation of cracks. As a matter of fact, traditional crack initiation criteria have been lately replaced by damage tolerance concepts, as pushed by the challenging requirements related to weight and, consequently, to fuel consumption. This applies for instance to blisks (blades and disk), in which a crack, triggered by vibrations at the blade root, may (depending on the propagation direction) grow through the disk and lead to the complete catastrophic failure due to centrifugal loading. In [6], the focus was on the calculation of the propagation direction by using two kink angle calculation criteria, i.e., the averaged angle criterion and the dominant step criterion. The prediction results were compared with the experimental data obtained with tension–torsion tests with and without considering a phase shift between the loads. It was found that the dominant step criterion demonstrated slightly better results for small to moderate values of the phase shift, whereas not very consistent results and no decisive conclusions were drawn for cases with a large phase shift of nearly 90°.

To further demonstrate the impressive ranges of applicability that fatigue and fracture simulations have reached nowadays, [7] presents an investigation related to another industrial sector, i.e., aerospace. In particular, a liquid rocket engine was analyzed numerically. These components usually need to be cooled regeneratively since they are characterized by very high levels of pressure and heat flux with the presence, within the inner structure, of very high thermal gradients. The aim was to implement a coupling and iterative methodology between two FEM models, a global (and linear) model and a local (and non-linear) model, in such a way to improve the accuracy of the numerical simulations but retaining, at the same time, a reduced computational effort. The results showed that significant accuracy improvements were achieved with respect to a modelling based on the only global analyses. This activity represented preliminary research in this topic and further steps ahead in this regard can now be found in the literature.

As mentioned previously, mechanical damage in the form of gouges, scratches, cracks, and dents is very common for pipelines. Occasionally, these damages develop close to each other and act as a single defect through the pipe wall, producing a synergetic impact, more injurious than the effects provided by the individual defects. The investigation presented in [8] used eXtended Finite Element Method (XFEM) criterion in Abaqus to simulate the burst pressure of specimens made of API X70 steel, with restrained and unrestrained concentric dent–crack defects. The XFEM models were calibrated and validated using the outcomes obtained by means of full-scale burst tests. The results suggested that dent–crack defects were not too dangerous for the integrity of the pipelines undergoing increasing levels of pressure. Anyway, further studies concerning more crack positions and dimensions within dents other than the apex (dent center) are needed for a more comprehensive understanding of the impact of dent–crack defects on the structural integrity of pipelines. Furthermore, the fatigue life of pipelines' dent–crack damages, which were not the specific objective of that investigation, require specific attention.

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Conflicts of Interest: The authors declare no conflict of interest.

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