

# Computational Methods for Fatigue and Fracture

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## 1. Introduction and Scope

Fatigue and fracture are pivotal issues in structural integrity. This area of research has attracted much attention over the last years, especially in regard to the main failure mechanisms, the understanding of which is pivotal to developing more durable and more reliable components. Modern numerical methods have been a strong ally in the improvement of current methodologies to assess the integrity of safety-critical components. Moreover, the permanent tendency to shorten time-to-market periods and to reduce overall costs faced by current industry is an additional ingredient for developing alternative simulation approaches because they allow high efficiency at the lowest possible cost. This Special Issue aims to focus on the new trends in computation methods to address fatigue and fracture problems. In this volume, seven papers addressing different research topics have been collected.

## 2. Contributions

The finite element method plays a key role in the numerical simulation of fatigue and fracture. Alshoaibi and Fageehi [1] developed an adaptive FEM-based approach for simulating the crack advance and the fatigue life in rectangular cross-section plates subjected to tension and bending. The numerical models considered a spider web mesh centred at the crack tip, and the stress intensity factors were computed using displacement extrapolation methods. Li and Xie [2], also basing their research on the finite element method, developed an algorithm to optimize the tooth surface contact stress in spur gears, considering tooth profile deviations, meshing errors, and lead crowning modifications. The problem was addressed using a three-dimensional model of one of the engaged teeth, by combining an optimized area of high refinement level with a non-refined area connected via multi-point constraint.

The analysis of critical engineering components by combining the finite element method with advanced fatigue methods was another line of research. Concli et al. [3] developed a critical-plane approach in conjunction with three-dimensional FEM models to study the early crack propagation stage in teeth subjected to bending fatigue. The models, created from extruded meshes and capable of accounting for boundary effects, allowed the determination of crack direction and the critical region associated with the crack nucleation. Sánchez et al. [4] determined the load-bearing capacity of tubular beams made of aluminium by applying the theory of critical distances and linear-elastic two-dimensional finite element models. The proposed methodology has been successfully validated for cantilever beams with circumferential U-shaped notches, leading to errors in the predicted load-bearing capacity lower than  $\pm 20\%$ .

Computational tools can play an important role in optimization problems. The paper by Khan et al. [5] presents a simulation-based optimization methodology for mold design and the prediction of reliability in mechanical components with minimum level of casting



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defects. The reliability was computed using classical strength–stress models and probability distribution functions. Woo et al. [6] proposed a parametric accelerated life testing approach to improve the fatigue life of mechanical components subjected to impact loading. The concept was tested in a domestic refrigerator hinge kit system, leading to a new design and an extended fatigue life. These promising results make the proposed parametric accelerated life testing approach applicable to metallic parts of other machines, namely cams, gears, crankshafts, and dies, to mention just a few.

In the context of fatigue crack propagation, the extended finite element method (XFEM) allows the alleviation of the shortcomings of the finite element method, namely with regard to the modelling of cracks and material interfaces. These advantages were explored by Fageehi [7], who studied the fatigue crack growth under mixed-mode loading in modified four-point bending beams and cracked plates with three holes. The fatigue assessment was conducted using fracture mechanics, stress-life methods, and strain-life methods. The proposed methodology was capable of simulating the crack paths, calculating the mixed-mode stress intensity factors at the crack front, and estimating the fatigue life for different geometrical configurations.

### 3. Conclusions and Outlook

The present Special Issue is aimed at collecting original contributions on the new trends in computation methods, which address fatigue and fracture problems. Seven papers were selected to cover a wide variety of current trends and applications. The topics addressed demonstrate that the finite element method remains a powerful technique in this field. However, other advanced tools are immersing, such as the extended finite element method or the meshless methods. In addition, the topics collected demonstrate the richness and the potential of current computational methods to deal with complex fatigue and fracture problems from different perspectives, namely the simulation of crack propagation in gears, the prediction of crack paths in notched plates, the calculation of critical loads in notched components subjected to different loading histories, the improvement of mold design and minimization of casting defects, and the development of advanced mechanical systems subjected impact loading. However, since numerical simulation of fatigue and fracture phenomena involves a myriad of problems, there are still open challenges that need to be addressed in order to translate scientific research into practical and daily life applications. In this context, guest-edited by the same team, a new Special Issue entitled “Numerical Methods Applied to Fatigue and Fracture Phenomena” ([https://www.mdpi.com/journal/metals/special\\_issues/numerical\\_fatigue\\_fracture](https://www.mdpi.com/journal/metals/special_issues/numerical_fatigue_fracture)) will be launched in *Metals*, to collect and disseminate the future advances in these areas.

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

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