Abstract

The Finite Fracture Mechanics (FFM) criterion is a coupled stress-energy approach introduced for the brittle fracture analysis of notched and cracked specimens. The criterion is based on a finite crack advancement and it requires, under incipient fracture conditions, the simultaneous fulfillment of a stress condition (involving the material tensile strength) and the energy balance (associated with the fracture energy). Similarly to other strength criteria based on the concept of a critical distance, FFM overcomes the limitations of Linear Elastic Fracture Mechanics (LEFM), which provides accurate predictions only for cracked specimens. However, unlike approaches within the Theory of Critical Distances (TCD) framework, the finite crack advancement predicted by FFM is a structural parameter rather than a material one. This distinction enables a more accurate description of size effects in configurations where the critical distance exceeds the ligament size. Analogously to FFM, the Cohesive Crack Model (CCM) involves a structural parameter and can be formulated by imposing a stress condition and an energy requirement. Several studies have compared these two approaches, demonstrating that FFM and CCM can yield similar strength predictions, depending on the configuration and the cohesive law adopted.

In this work, all these approaches will be reviewed and compared across different configurations and loading conditions, considering both static and fatigue regimes.
In the static regime, the study explores the failure size effect in cracked and holed components. This includes configurations such as circular holes in tensile slabs and flattened disks under compression. Furthermore, the ligament size effect and the crack shielding phenomenon are investigated, considering edge-cracked plates and cracked cylindrical bars. Experimental results are carried out and analyzed using both semi-analytical and full Finite Element implementations. Moreover, to further validate the proposed models, strength predictions are compared to those provided by TCD and CCM.

In the fatigue regime, the FFM criterion is initially applied to investigate the failure size effect of spheroidal voids, comparing strength predictions with experimental data arising from different steel structures with corrosion pits. Then, a semi-analytical implementation of the FFM approach is proposed to assess fatigue limits of V-notched bars under combined mode I/III loading. The model is validated through a wide range of experimental data for different materials and loading conditions, confirming the reliability of the FFM criterion in predicting fatigue strength.

The findings presented in this work confirm FFM as a robust and versatile tool for predicting crack onset in complex mechanical systems, offering valuable strength predictions that can be applied in engineering design practice. Compared to other fracture mechanics criteria, the FFM approach demonstrates greater accuracy in predicting failure for various structural configurations compared to methods within the TCD framework. Additionally, its implementation requires less computational effort than the CCM criterion. On the other hand, CCM is better suited for predicting crack growth paths compared to FFM. In conclusion, the work significantly expands the range of problems to which FFM can be applied, showcasing its potential to handle real-world challenges in structural integrity.