

Guest Editorial: Characterization of Crack/Notch Tip Fields (CCTF7)

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Guest Editorial: Characterization of Crack/Notch Tip Fields (CCTF7)

Youshi Hong, Michael Vormwald, Luca Susmel, Giovanni Meneghetti, Thierry Palin-Luc

This virtual special issue contains selected and fully peer-reviewed papers from the 7th IJFatigue and FFEMS Joint Workshop on Characterization of Crack/Notch Tip Fields (CCTF7) held in Padua, Italy, on June 5–7, 2024.

For the last 50 years, single-parameter characterization of the crack/notch tip field using fracture mechanics parameters like K , J , or CTOD has been extremely powerful in advancing predictive technologies for critical or subcritical crack growth. It has also become clear over recent decades that the approximation inherent in single-parameter approaches has limitations, particularly in dealing with crack growth phenomena arising from crack tip shielding. This has naturally led to a considerable research effort towards alternative approaches to understand the physics of fatigue crack growth rate, determine better similitude parameters, and predict remnant life. Endeavors have ranged across, for example, energy, plastic zone size or area, and multiparameter models. These research endeavors have been greatly aided by the development and availability of advanced full-field experimental measurement techniques, including digital image correlation (DIC), thermographic stress analysis, and electronic speckle pattern interferometry (ESPI) for 2D and 3D measurements of crack and notch tip fields.

Although the research future seems brighter than it has ever been in terms of instrumentation, numerical modeling and even crack tip field models, interaction between people working with different techniques and ideas on similar problems, remains elusive. It was with this in mind that this workshop series was started in 2011 in Forni di Sopra, Italy, with strong support from the Italian Fracture Group. Subsequent conferences have taken place in Malaga, Spain (2013); Urbino, Italy (2015); Bonifacio, Corsica, France (2017); Heidelberg, Germany (2019), Dubrovnik, Croatia (2022); and now Padua, Italy, in 2024.

The workshop has retained the successful format, based on a largely invited group of delegates, of allowing adequate time for discussion after each paper presentation. The conference committee firmly believes that time for delegate interaction after each session is key to encouraging networking and the development of new ideas. A final overall discussion session summarizes the work presented and focusses on identifying key themes for future research.

Thirteen papers selected and peer-reviewed for this Virtual Special Issue of FFEMS present a range of research that illustrates both the complexity of the topic and presents some of the current research endeavors that are giving detailed consideration to a number of these aspects. Below are brief highlights of such contributions.

Schneider and Kästner [1] developed a finite-strain phase-field fracture model for periodic heterogeneous media using fast Fourier transform solvers. The calculations agreed well with FEM results. 2D and 3D simulations confirmed related reliability and efficiency. This approach facilitates further research on inverse design of metallic microstructures.

Short fatigue crack behavior of coaxial powder-fed laser cladding K477 superalloy was studied by Huang et al. [2] via in situ SEM under different stress ratios and temperatures. Three ensemble learning algorithms were adopted with random forest gave the best result, indicating machine learning predictions agree well with measured fatigue life.

Jin et al. [3] performed 2D plane stress FEA to investigate the effects of orthotropy, crack length, and loading angle on elastic mode mixity and T-stress and showed predicted crack initiation angles under small-scale yielding conditions. This provides a new perspective for

compact tension shear tests in determining mixed-mode fracture mechanisms of anisotropic materials.

Li et al. [4] reported that microstructurally small cracks exhibited a V-shaped growth rate of a Ni-based superalloy by in situ tests. Notches activated multiple slip systems, and intragranular cracks propagated along slip bands. Cross-slip, grain boundaries, and carbides deflected crack paths. The established crack growth models provided reliable fatigue life predictions.

The fatigue behavior of L-PBF Scalmalloy, a high-performance alloy for aerospace and automotive use, under different surface states and build orientations was investigated by Perghem et al. [5]. The results revealed that R-curve approaches provide more conservative predictions. Their findings support fatigue life prediction and defect-tolerant design for AM components.

Montanari et al. [6] investigated puncture failure of elastomeric membranes under spherical indentation. An axisymmetric model for hyperelastic incompressible membranes was proposed and validated by tests. Considering stretch- and energy-based fracture criteria, they clarified the conditions for membrane failure and crack propagation.

A novel method for determining crack tip opening loads was proposed by Khanna et al. [7] based on the strip yield model. The inflection point of compliance offset curves accurately indicated crack opening initiation, avoiding errors from empirical criteria. Experimental results verified that this method eliminates R-ratio effects on fatigue crack growth under various loading conditions.

Marghitas et al. [8] reported that the fracture properties of 3D printing parts by digital light processing depend on processing parameters. They used two resins to fabricate standard specimens via an Anycubic Photon printer. Test results confirmed obvious size effects consistent with asymptotic matching. The critical distance theory can predict notch-induced fracture loads.

Sedmak et al. [9] investigated the stress concentration induced by notch/crack on the impact toughness of S32750 duplex steel via Charpy tests. The results showed that total energy was divided into crack initiation and propagation parts. The crack sensitivity factor was calculated at different temperatures and fatigue crack lengths. Fractography was also examined.

Sérgio et al. [10] adopted a node release criterion to predict FCG in AA6082-T6 alloy. Numerical models under various stress states were validated against experiments for constant and variable amplitude loadings. A 3D plane-stress model gave best predictions. However, the models failed to capture the thickness-dependent FCG trend, which requires full-thickness 3D simulations.

Tsakmakis et al. [11] performed numerical studies on multiaxial fatigue crack growth in ductile materials under proportional and nonproportional cyclic loading using a phase field fracture theory to analyze size effects and compare with test data. Predictions agreed well with experiments for proportional loading, whereas discrepancies existed for nonproportional loading.

Pre-cracked specimens are commonly used to study defect-initiated cracks, yet fatigue pre-cracking under specific loading can generate strong residual stress near crack tips. Pippan et al. [12] used a dislocation analysis to evaluate residual stress induced by cyclic compression loading and proposed feasible strategies to reduce residual stresses.

Cerezo et al. [13] used the method by Kujawski and Vasudevan to assess the measurement of ΔK_{th} and $K_{max,th}$. Based on actual crack propagation, they developed a new approach for more efficient fatigue threshold evaluation of long cracks, which would also reduce testing time and post-processing work.

Finally, the Guest Editors of this special issue warmly thank all the delegates and authors for their contributions and hope that this overview of current thinking in the area of crack and notch tip fields in relation to fatigue and fracture is useful for the research community.

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