**20th European Mechanics of Materials Conference - EMMC20**
Florence, Italy | May 27th-29th, 2026
www.emmc20.unifi.it

# Fatigue crack growth under variable amplitude loading using phase-field method

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*Paper ID: 488*
*Symposium S9: Fatigue evaluation: modelling and characterisation at different length scales*

## Abstract

Material failure prevention is necessary and crucial for safe and reliable operation of nuclear power plants. The structural response of safety-related components can be significantly affected by the appearance and propagation of fatigue cracks. Thus, modeling of crack growth to improve our understanding of fatigue damage is an important task. There are many methods and approaches to model fatigue crack growth; however, they typically suffer from empirical definitions, high number of model parameters, limited use beyond constant amplitude loading (CAL), and complicated numerical implementation. In recent years, phase-field method (PFM) has gained popularity since it is able to model initiation and propagation of cracks while being crack-path independent. PFM stems from regularized Griffith theory, which smears a discrete crack to a continuous one. Fatigue damage is added to the PFM model with a fatigue degradation function to accumulate damage over time. More complex loads, such as variable amplitude loads (VALs), are known to have different effects on crack growth. A simple example of a VAL is an overload, which is a single cycle of higher amplitude within a constant amplitude loading. The overload generally retards the crack growth due to increased hardening at, and compressive residual stresses in front of, the crack tip. In general, VALs can be composed of blocks of cycles with different amplitudes. The PFM model used in this work has been enriched with plastic material response, including hardening, and the strain energy density decomposed to remove crack growth under negative elastic strains. The model is implemented in the finite element

code Abaqus using subroutines. The work has been divided in two parts: (i) single overloads within CALs and (ii) different configurations of VAL blocks, both to study their influence on fatigue crack growth. The results include comparisons of crack length versus number of cycles, Paris law behaviors, as well as stress and plastic strain distributions.

**Keywords:**

Phase-field method Fatigue crack growth Variable amplitude loading Overload Elasto-plastic constitutive model Cyclic hardening