

# FATIGUE LIFE PREDICTION FRAMEWORK FOR STEELS BASED ON MULTISCALE MODELLING OF CRACK GROWTH

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## Abstract

In this study, we established a framework for predicting the fatigue life of ferritic steels using a multiscale modelling strategy. The multiscale model estimates total fatigue life from crack growth life alone, based on experimental facts.

The model consists of three sub-models: (i) macroscopic finite element analysis, (ii) microstructure, and (iii) crack growth. The input data required are microstructural information, tensile properties, and loading conditions, without any adjustable material constants. The macroscopic finite element analysis aims to define an active zone that includes all possible crack initiation areas and to obtain the strain amplitude field in this zone. For the microstructure model, we used a two-step 2D modelling strategy to represent surface and internal material features, considering actual fatigue crack initiation and growth behaviours. The Monte Carlo method simulates microstructure distribution, reflecting the natural scatter of fatigue life. In the crack growth model, we employed the interaction theory between cracks and grain boundaries, quantifying the driving force represented as the crack tip sliding displacement (CTSD) based on continuously distributed dislocation theory. All grains in the surface of the active zone are considered potential crack initiation sites, and the number of cycles to failure is determined using the weakest link assumption.

The model was strictly validated against experimental results from tests on three different steels under various loading conditions using four types of specimens. Despite the wide variation in experimental results, the predicted results showed good agreement with the experimental data. The model successfully reproduced the notch sensitivity of fatigue limits depending on material strength and accurately predicted the transition of the crack growth rate from the crack initiation to the long crack growth behaviour.

These findings demonstrate that the framework for predicting the fatigue life of ferritic steels was effectively established based on the multiscale modelling strategy simulating crack growth.

## Keywords

Fatigue; Life prediction; Multiscale modelling; Small crack growth; Validation

## References

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