NME 2025

Investigation of the effect of Axial and Normal Stress Ratios on Fretting Fatigue Crack Initiation and Propagation

Paper ID : NME1561

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Introduction

A novel investigation into the influence of out-of-phase cyclic normal load and axial stress ratios on fretting fatigue crack initiation and propagation behaviours.
Unlike previous studies that primarily focus on constant normal load, our research employs advanced numerical models to provide for the first time a detailed analysis of the effect of out-of-phase cyclic normal load on fretting fatigue crack initiation and propagation behaviours.

Methods

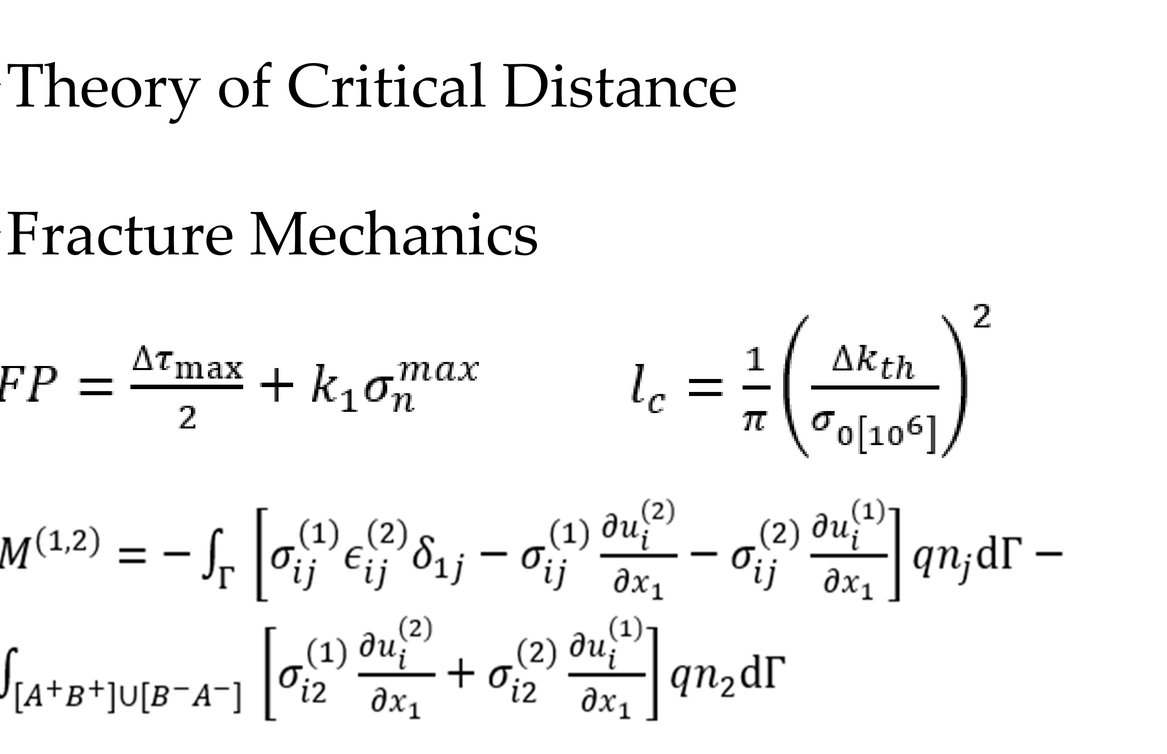
- Critical Plane Method
- Theory of Critical Distance
- Fracture Mechanics

$$FP = \frac{\Delta\tau_{\max}}{2} + k_1\sigma_n^{max} \qquad l_c = \frac{1}{\pi}\left(\frac{\Delta k_{th}}{\sigma_{0[10^6]}}\right)^2$$

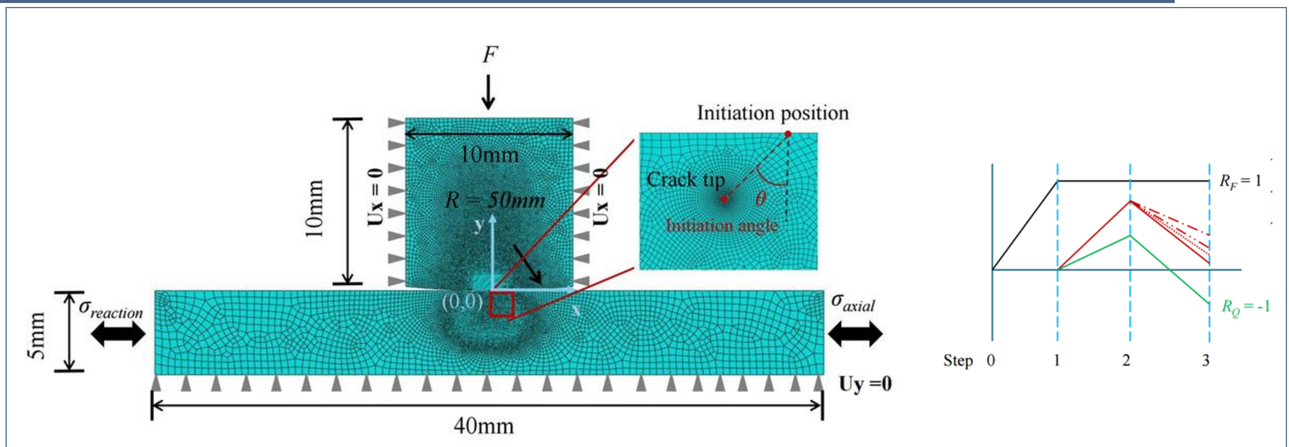
$$M^{(1,2)} = -\int_\Gamma \left[\sigma_{ij}^{(1)}\epsilon_{ij}^{(2)}\delta_{1j} - \sigma_{ij}^{(1)}\frac{\partial u_i^{(2)}}{\partial x_1} - \sigma_{ij}^{(2)}\frac{\partial u_i^{(1)}}{\partial x_1}\right] qn_j \mathrm{d}\Gamma -$$

$$\int_{[A^+B^+]\cup[B^-A^-]} \left[\sigma_{i2}^{(1)}\frac{\partial u_i^{(2)}}{\partial x_1} + \sigma_{i2}^{(2)}\frac{\partial u_i^{(1)}}{\partial x_1}\right] qn_2 \mathrm{d}\Gamma$$

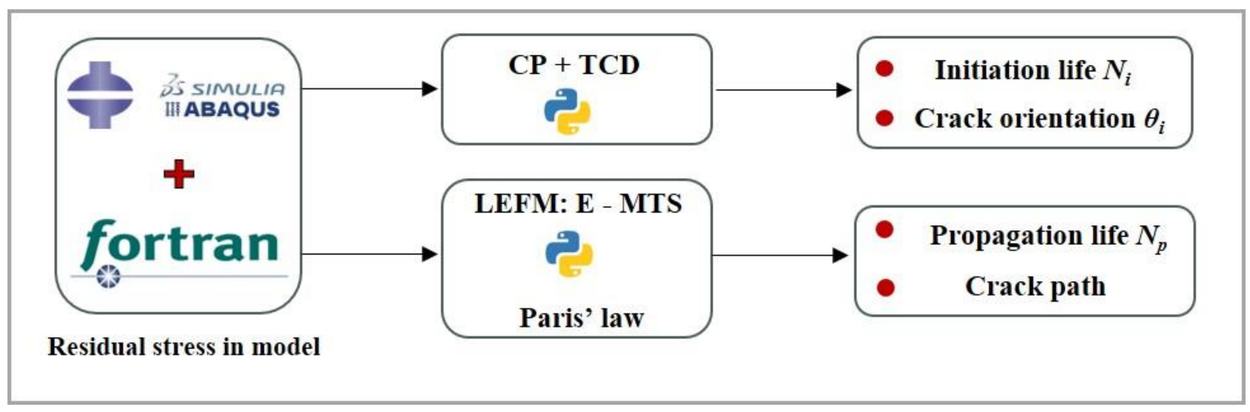
Graphics / Images



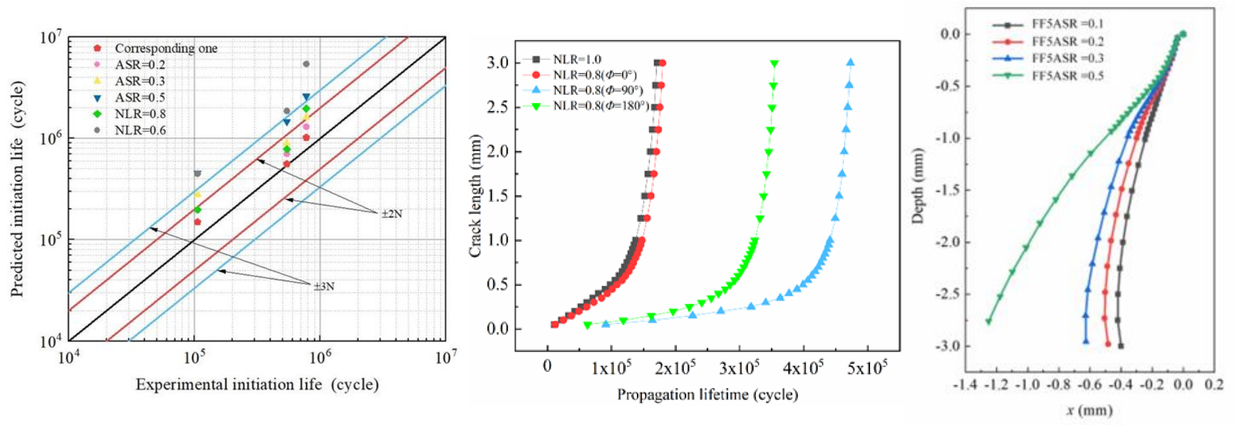
Multi-axial load on contact behaviour and fretting fatigue lifetime



Model Construction: FEM



Postprocess Based on the results from Abaqus solver



Crack initiation and Propagation estimations

Conclusions

1. ASR has a more pronounced effect for high load, whereas NLR has a stronger influence for low load. Reducing NLR generally increases crack initiation lifetime, but under out-of-phase loading conditions, particularly at Φ = 90°, this benefit is significantly reduced, highlighting the strong influence of phase shift on the crack initiation process.

2. Cracks generally propagate towards the contact region, with a tendency for cracks to shift toward the center as both ASR and NLR increase.

3. The enhancement ratios of crack propagation lifetime are less significant than those of crack initiation lifetime with varying ASRs. Under different NLRs, the effects may be negative, and any positive effects are relatively minor compared to those of ASRs. However, out-of-phase loading (particularly Φ = 90°) provides a significant advantage in extending propagation lifetimes