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Fracture Fatigue and Wear

Fatigue Lifetime Prediction of Dovetail Joints Using Frictional Dissipation Energy under Temperature Effects

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Introduction

This study proposes a fretting fatigue life prediction method based on frictional dissipation energy (FDE), focusing on dovetail joint contact structures. The method incorporates temperature effects and integrates shear friction forces and relative slip over the entire loading–unloading process within a single loading cycle to realistically capture cumulative damage evolution. By identifying the position of maximum FDE at the contact interface and establishing a quantitative relationship with fatigue lifetime, a unified predictive model applicable to both room and high temperature conditions is developed.

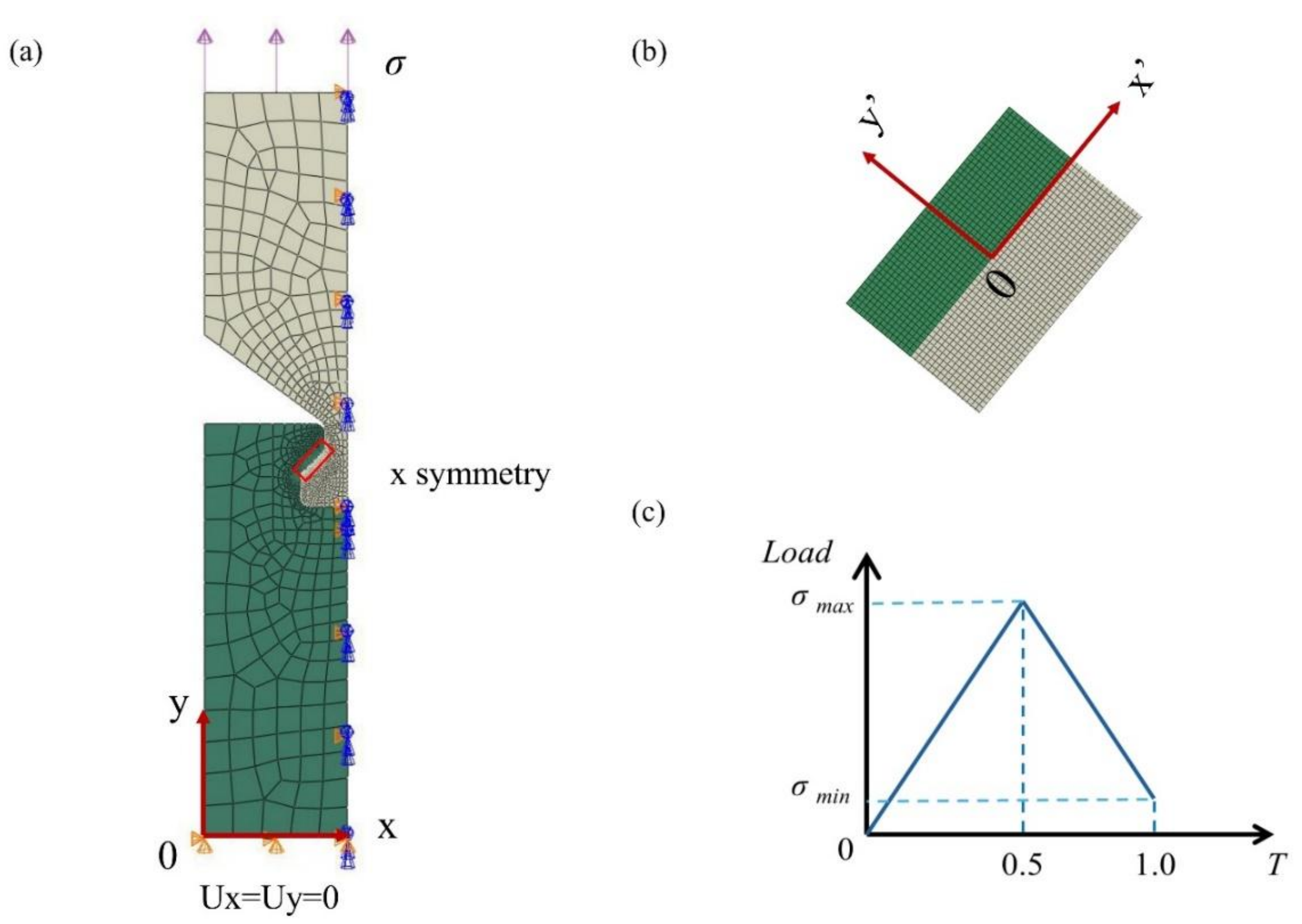
Methods

- Finite Element Method
- FDE-based fretting fatigue prediction model
- Temperature-corrected fretting fatigue prediction model

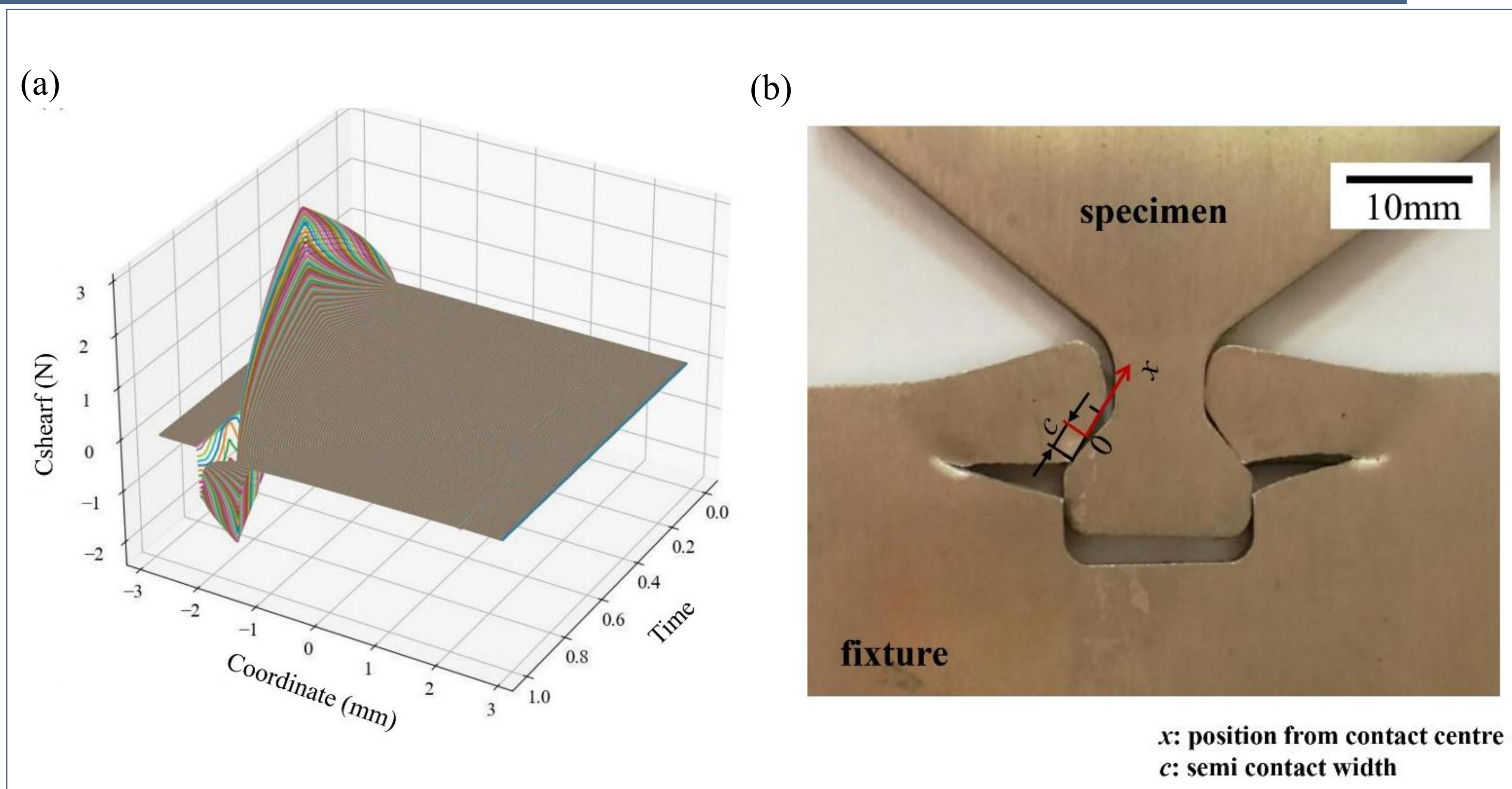
$$W_i = \int_0^{t_n} f(t)\Delta x(t)dt$$

$$N_i = k \times \left(\frac{1}{W_{max}}\right)^a \times \left(\frac{T_m - T}{T_m - T_R}\right)^b$$

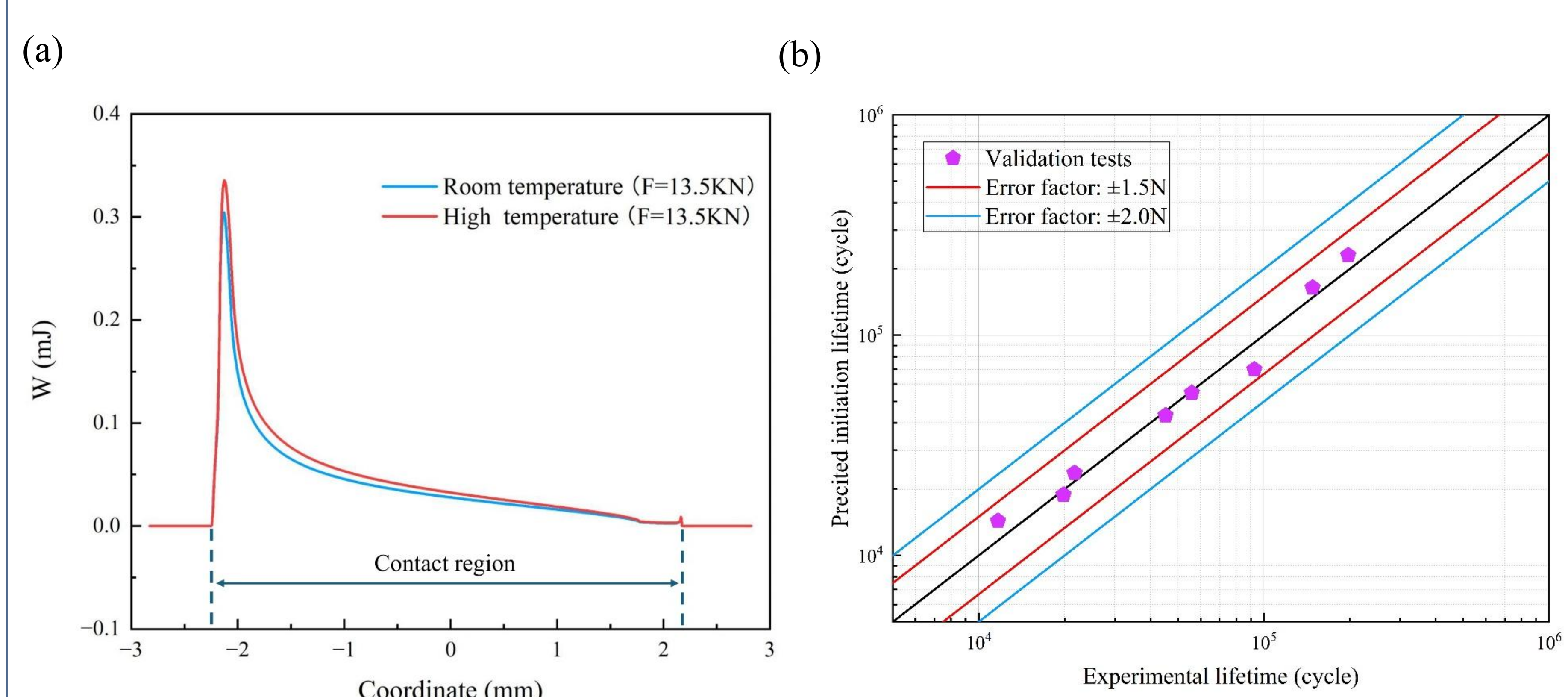
Graphics / Images



The 2D numerical model for the dovetail joint model:
(a) boundary conditions, (b) enlarged view of the contact region, and (c) application of



Numerical and Experimental Results for T1-2
(a) 3D distribution of friction and (b) crack initiation positions in T1-2.



Analysis of frictional behaviour and lifetime prediction
(a) Distribution of FDE under different temperature and (b) Comparison between experimental and predicted crack initiation lifetime

Conclusions

1. From a temporal perspective, the friction force varies synchronously with the applied load throughout the loading cycle. From a spatial perspective, a sharp local friction peaks appearing at the lower contact edge in phase with the maximum applied load. This indicates that fatigue damage is most severe in this region and is primarily governed by the applied load.
2. High temperatures significantly increase energy dissipation at the contact interface, which can accelerate fatigue crack initiation and reduce the corresponding lifetime.
3. Under high load and high temperature, the crack initiation position slightly shifts toward the centre of the contact region, yet it consistently remains at the lower edge of the contact area.
4. A new method for predicting fatigue lifetime based on FDE has been proposed. The method effectively captures the cumulative energy dissipation throughout the entire loading–unloading process within a single loading cycle and demonstrates excellent predictive performance under both room temperature and high temperature conditions, with prediction errors controlled within ± 1.5 band.