FFW 2026

Fracture Fatigue and Wear

Unveiling the Synergistic Mechanisms of Hybrid LSP and SP in Mitigating Fretting Fatigue of Ti-6Al-4V

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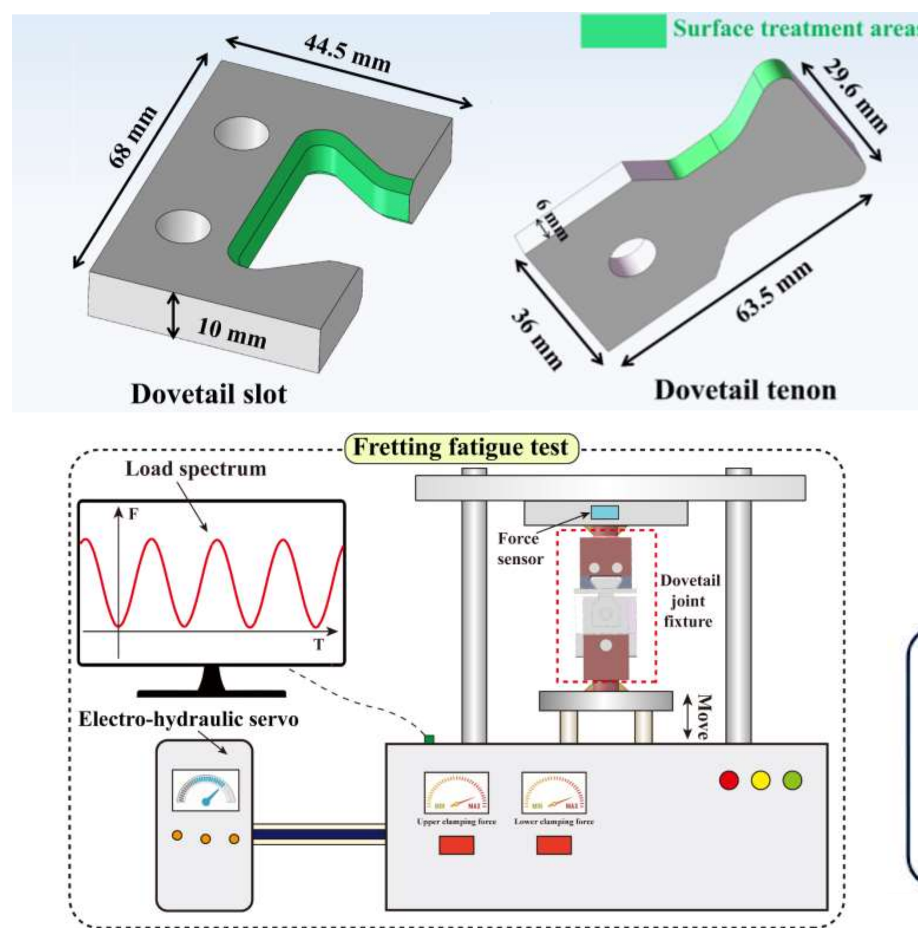
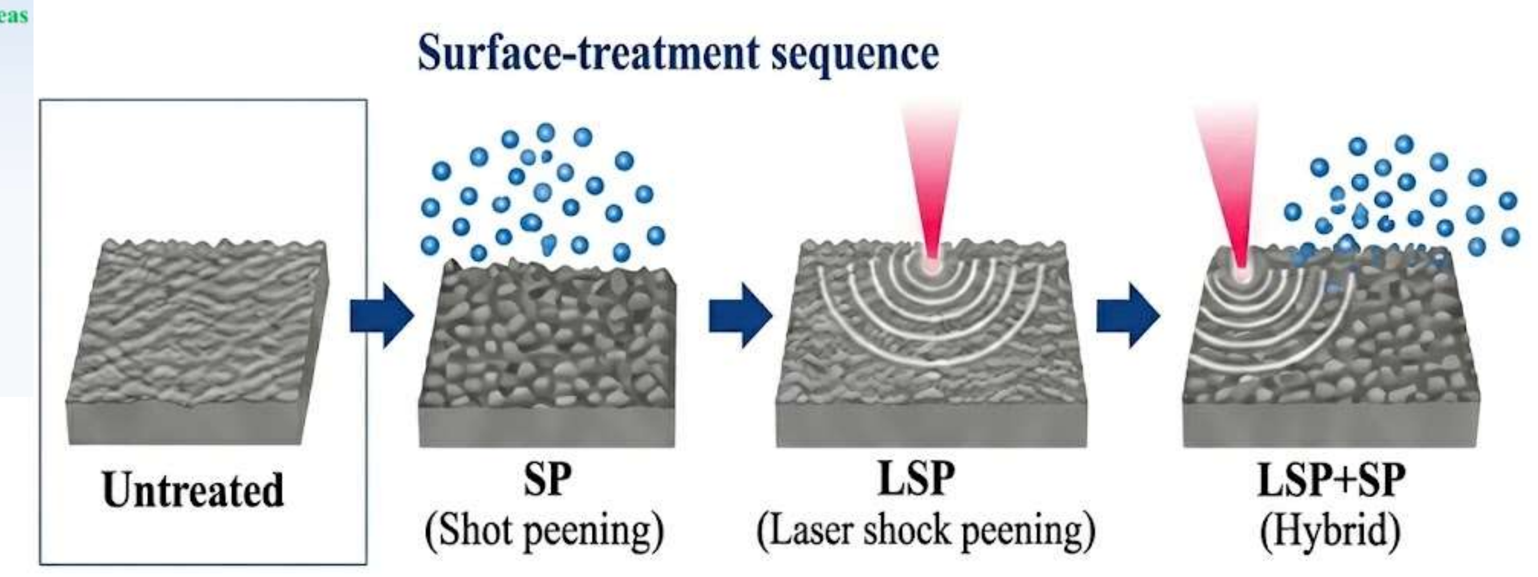
1. Background

- Fretting fatigue in Ti-6Al-4V dovetail jointsis a critical threat to aero-engine reliability.
- This study evaluates whether hybrid lasershock peening plus shot peening (LSP+SP)can outperform single treatments.
- The goals are to reveal synergisticstrengthening mechanisms and establisha physically informed life-predictionframework.

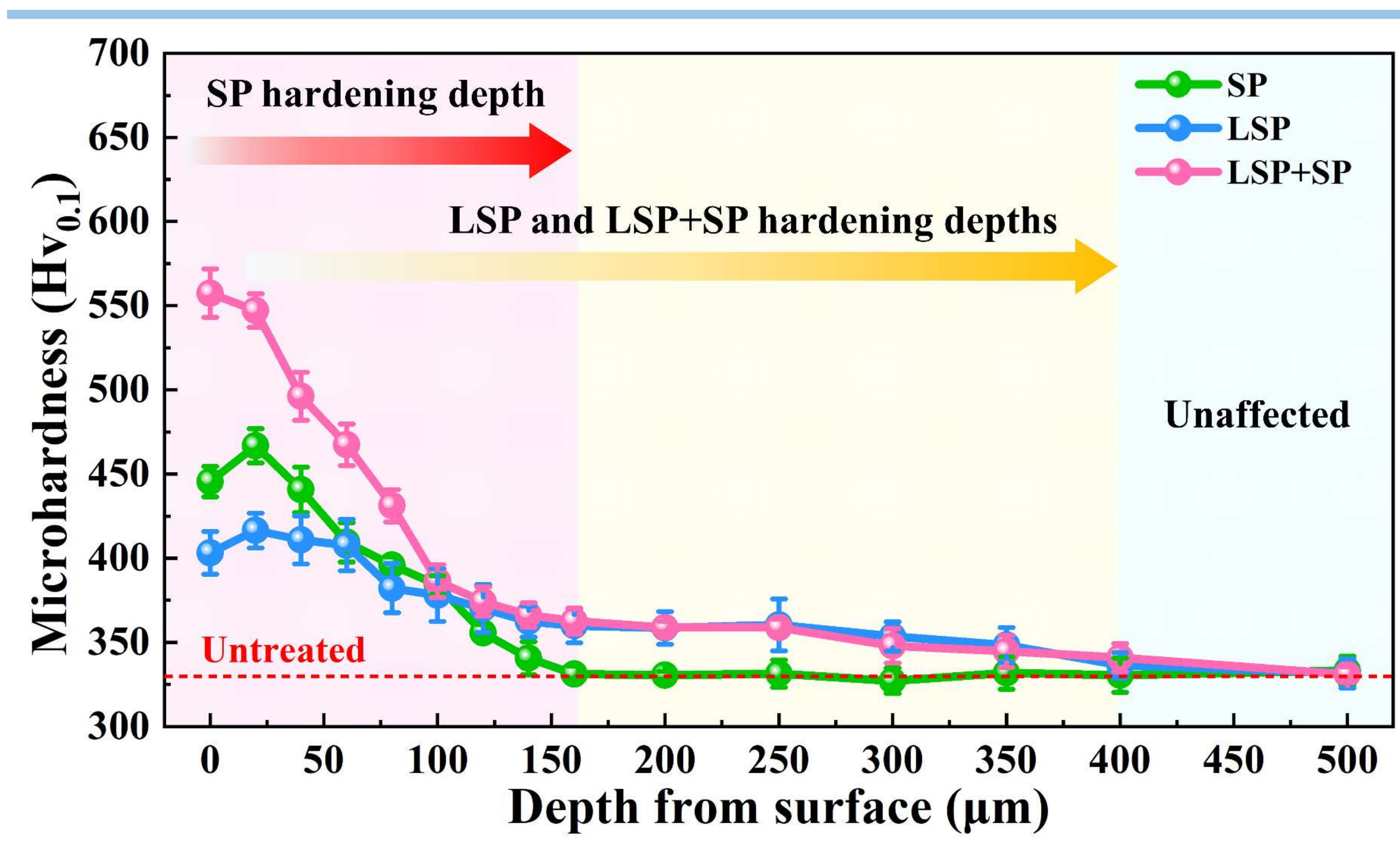
2. Experimental Strategy

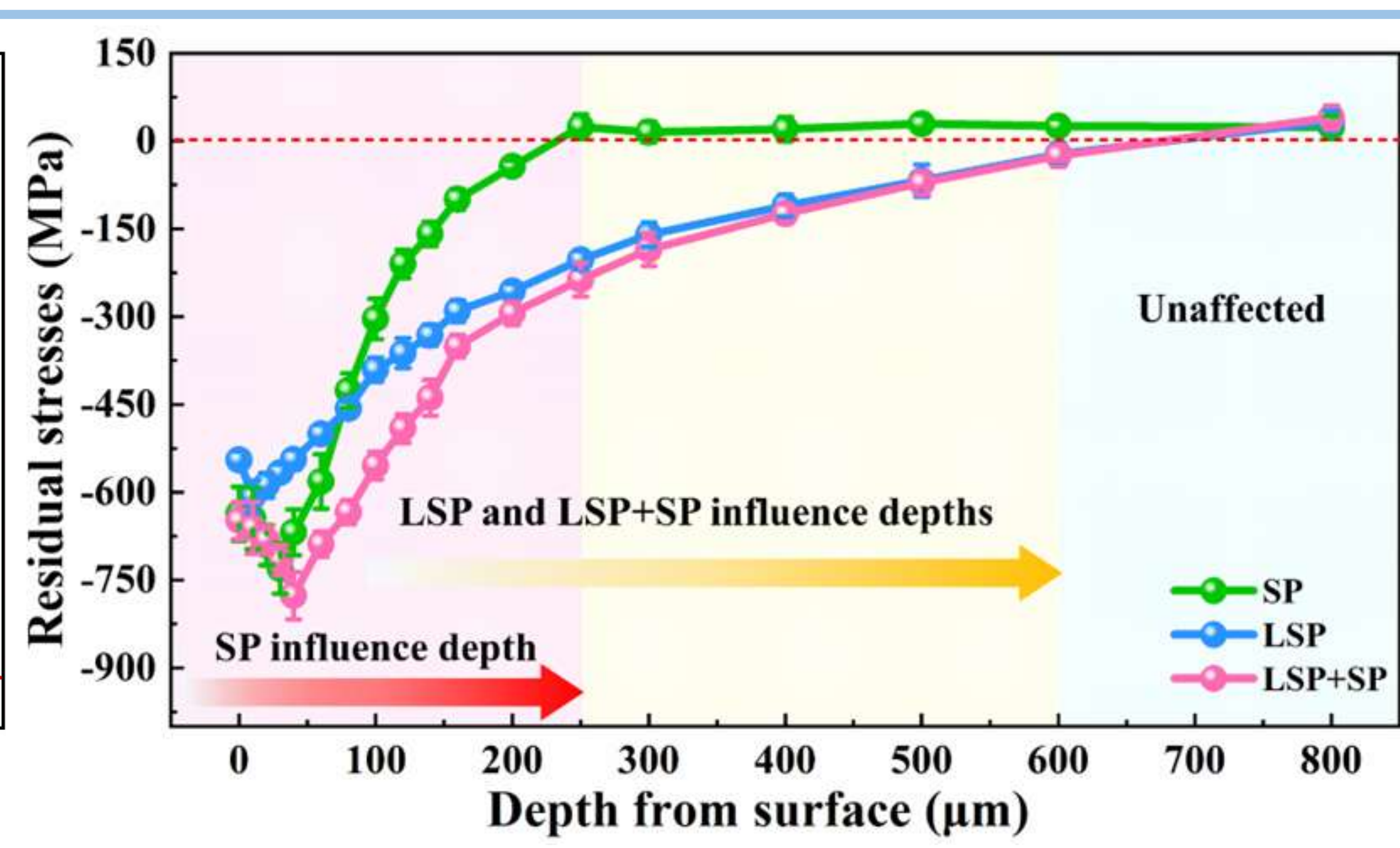




- ✓ Material: Ti-6Al-4V dovetail slot/tenon specimens
- ✓ Treatments: Untreated, SP, LSP, and hybrid LSP+SP
- ✓ FF tests under combined cyclic loading, peak loads 26–40 kN
- ✓ In-situ crack monitoring and FEM-assisted life prediction

3. Key surface integrity results





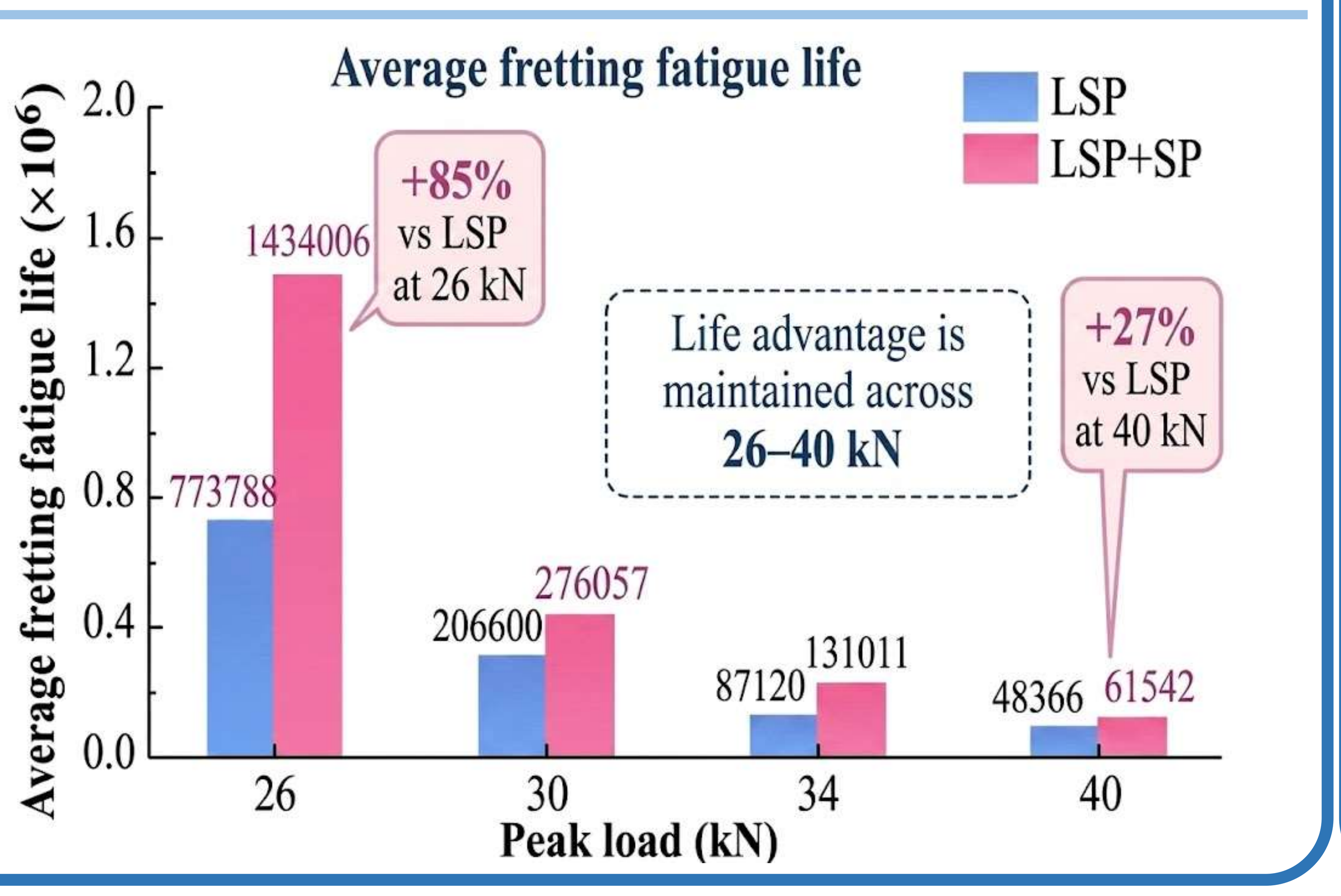
Maximum hardness: 557.4 HV

Peak compressive residual stress: -776.6 MPa

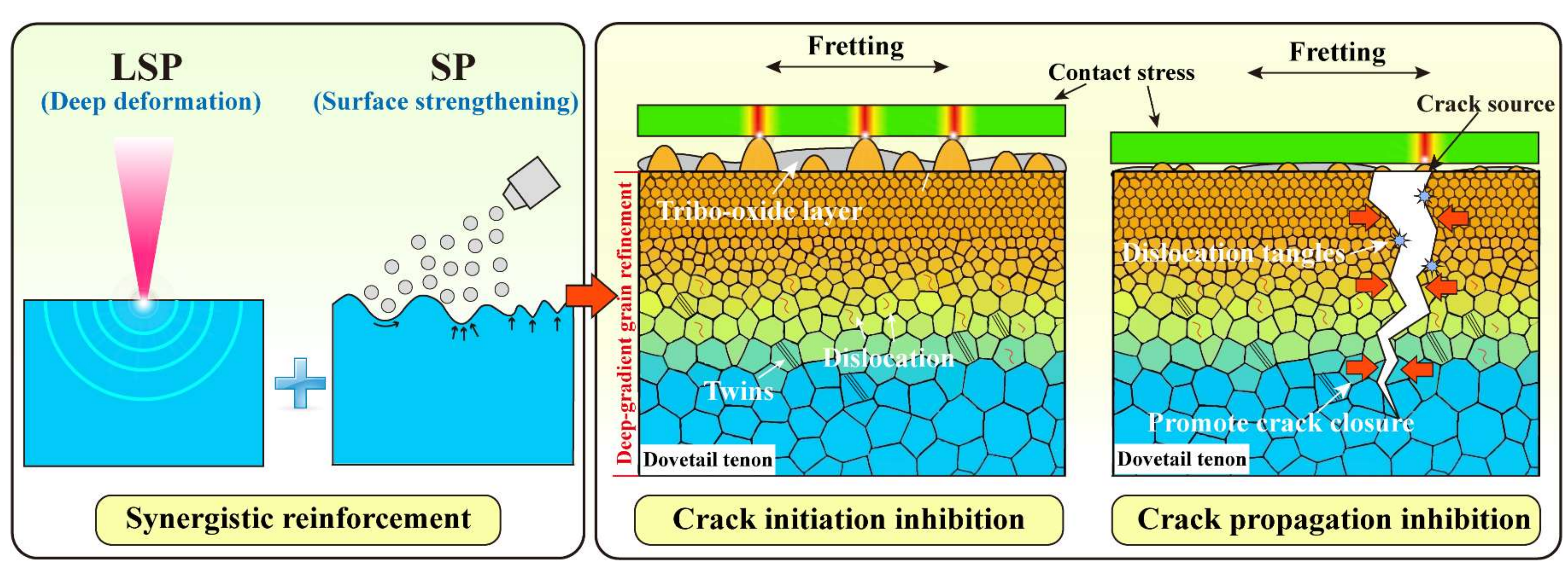
LSP+SP combines high near-surface hardening with a deep affected layer comparable to LSP

Ultrafine grains (~1.33 μm) formed in the top 50 μm; refined layer extends to ~250 μm

4. Fretting fatigue performance

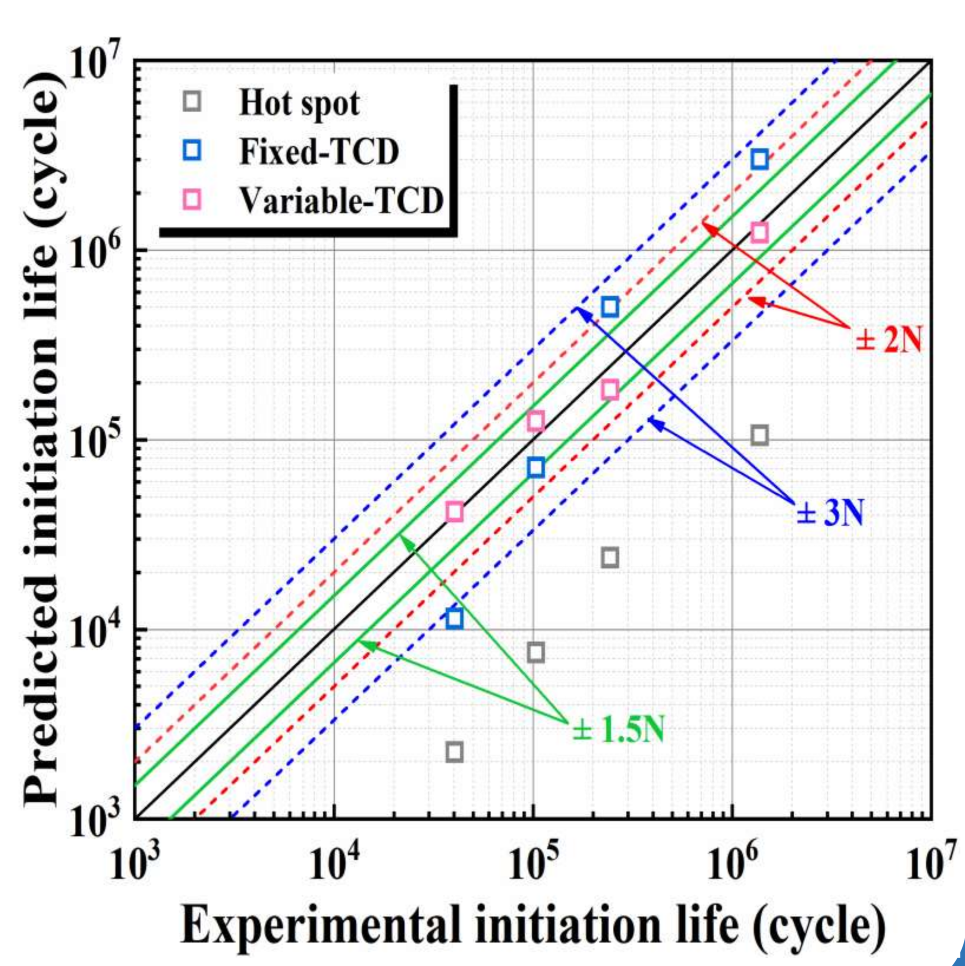


5. Synergistic enhancement mechanism



6. Fretting fatigue performance

- A FEM-based SWT +variable-TCD frameworkwas developed using theactual gradient CRS distribution.
- Variable.TCD outperformedthe hot-spot andfixed-TCD methods.
- All initiation-lifepredictions fell within the1.5x scatter band.



7. Main conclusions

1. Hybrid LSP+SP generated a superior gradient nanostructure withstrong near-surface hardening and deep compressive residual stress.
2. The treatment markedly improved fretting fatigue resistance bysimultaneously delaying crack initiation and retarding early crackgrowth.
3. The proposed SWT + variable-TCD model provided accurateinitiation-life prediction for gradient-strengthened dovetail joints.
4. LSP+SP is a promising surface-engineering route for criticalaero-engine Ti-6Al-4V components.