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Fracture Fatigue and Wear

Dwell Time-Induced Microstructure Evolution in an Fe-Ni-Based Superalloy

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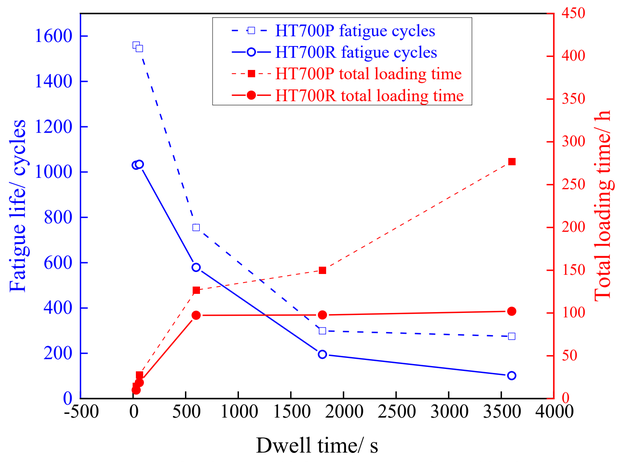
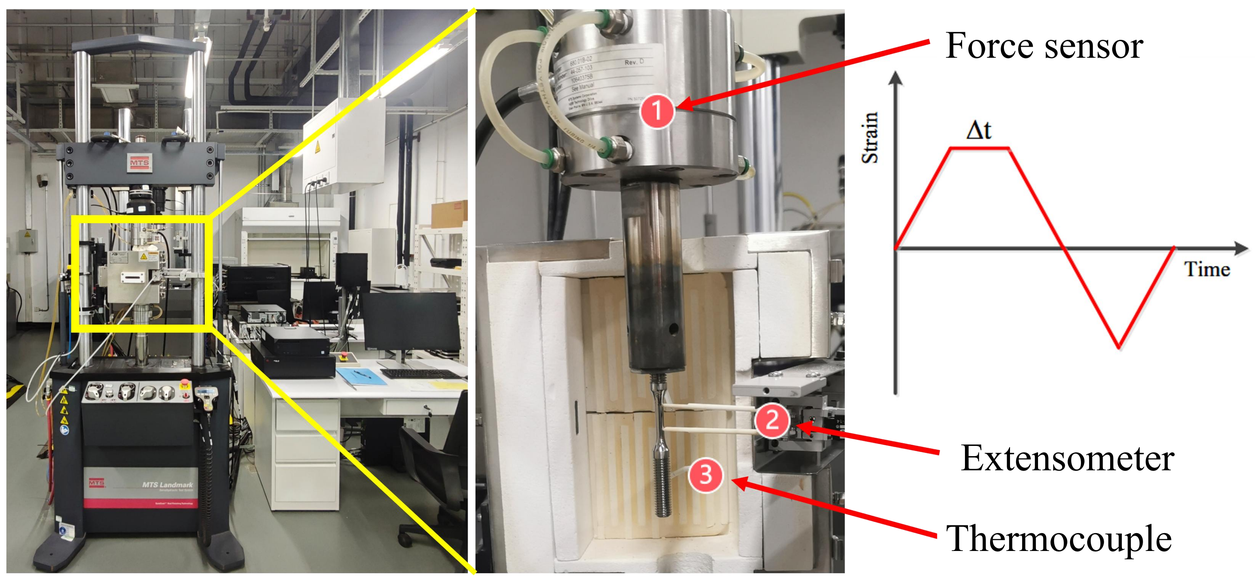
Introduction

Creep-fatigue is a major failure mode under high-temperature long-term service. The microstructure evolution of an Fe-Ni-based superalloy under creep-fatigue loading was studied at 650°C and 0.5% strain amplitude with dwell times of 30–3600s. EBSD and TEM were used to analyze the microstructure evolution and reveal the underlying damage mechanisms.



Creep fatigue life along dwell time

Methods



Strain controlled creep fatigue test system

Materials: iron-nickel based alloy

Temperature: 650°C

Strain: 0.5%

Dwell time: 30s, 60s, 600s, 1800s, 3600s

Analysis methods:

SEM

TEM

EBSD

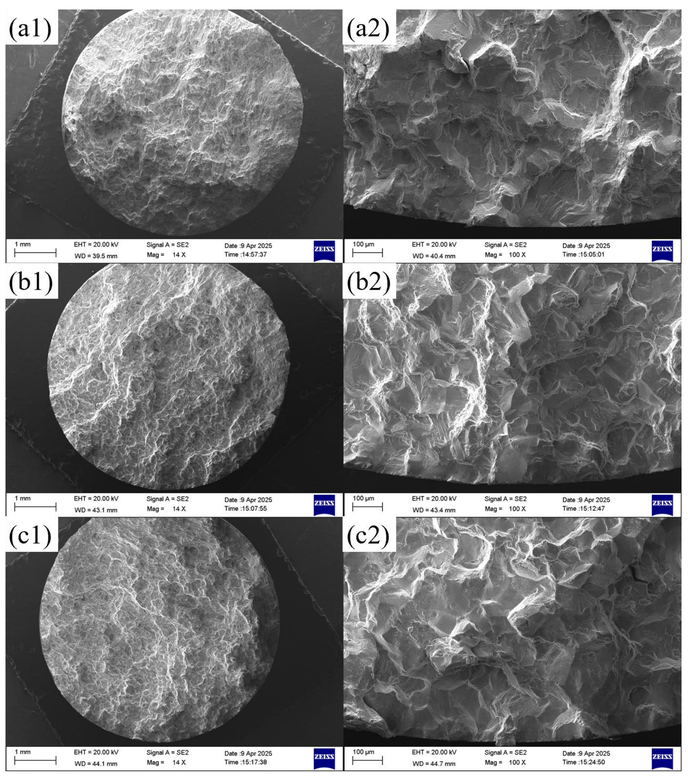
Graphics / Images

With increasing dwell time from 30s to 600s, fracture mode shifts from transgranular fatigue to intergranular creep-dominated failure.

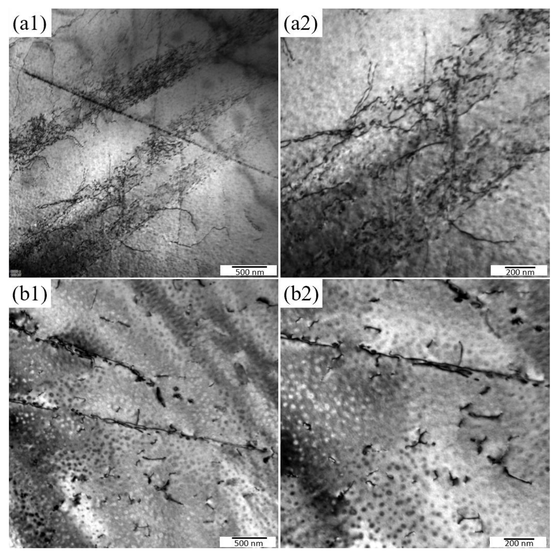
At 30s: flat fracture, transgranular cracks (fatigue).

At 60s: rougher fracture, intergranular tendency.

At 600s: pronounced intergranular fracture, clear grain boundaries, numerous secondary cracks (creep-dominant). For dwell time >600s, transverse cracks appear on surface; failure defined as 25% load drop.

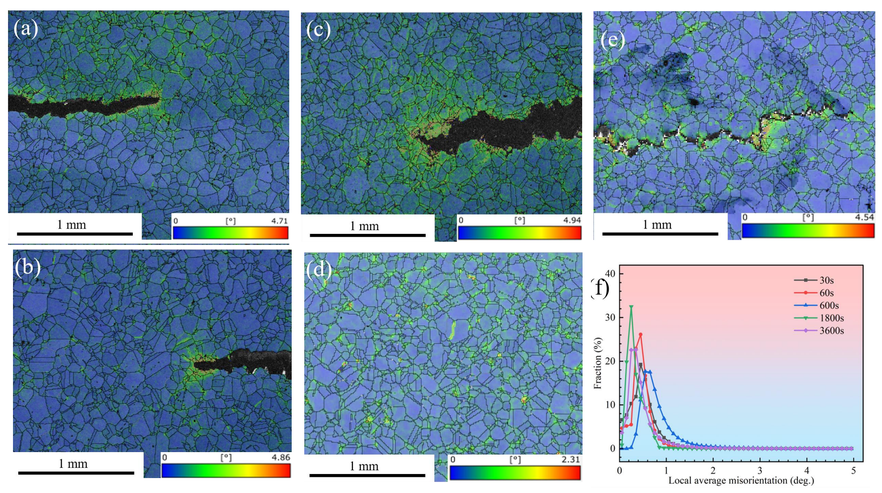


Fracture morphologies at 650°C with a strain amplitude ε0.5% under different dwell times: (a1, a2) 30 s; (b1, b2) 60 s; (c1, c2) 600 s.



TEM morphologies of creep-fatigue specimens at 650°C with a strain ε = 0.5% under different dwell times: (a1, a2) 30 s; (b1, b2) 3600 s

at 650°C with Δε/2 = 0.5%, the Fe-Ni-based superalloy exhibits different dislocation structures with dwell time. At 30s, dislocation slip dominates, forming high-density straight slip bands with complex entanglements (fatigue-dominated). At 3600s, dislocation density drops significantly, entanglements transform into regular dislocation walls, and localized recrystallization occurs (creep-dominated). Prolonged dwell time shifts the deformation mechanism from slip-dominated to slip-climb co-action.



LAM maps of Fe-Ni based alloy under different dwell times

LAM increases from 0.3°-0.5° (30-60s) to 4.94° (600s), then drops to 2.31° (1800s), and rises to 4.54° (3600s). This reveals the transition from fatigue-dominated to creep-dominated damage with increasing dwell time.

Conclusions

The influence of dwell time on the microstructure evolution in an Fe-Ni-Based superalloy was studied, the conclusions are as follow:

1, Creep damage increases with dwell time. Fatigue life decreases but total test duration increases with longer dwell time.

2, Under short dwell times (30–60s), dislocation slip dominates and LAGBs prevail, with fatigue as the primary failure mechanism.

3, Under medium to long dwell times (600–3600s), dislocation climb is activated, HAGBs and recrystallized grains increase, and creep damage becomes dominant. The alloy exhibits good microstructural stability at 3600s.

4, The transition from LAGBs to HAGBs shifts crack propagation from intergranular to intragranular, promoting the transition from fatigue-dominated to creep-dominated failure.