Karlsruher Institut für Technologie

KIT – Karlsruhe Institute of Technology

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Creep-fatigue interaction in ODS steels

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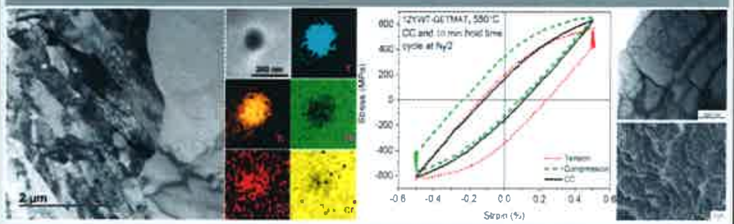
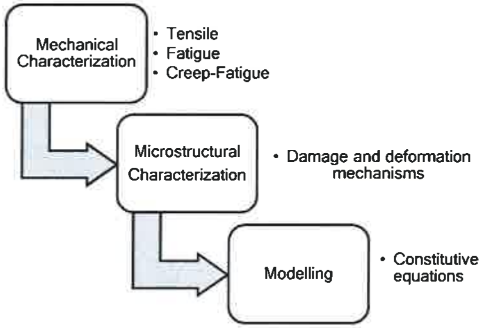


Objective

MATISSE

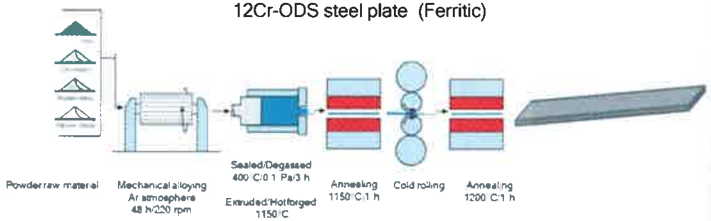
Investigating and characterizing the deformation and damage mechanisms of ODS steels



Material

GETMAT

12Cr-ODS steel plate (Ferritic)



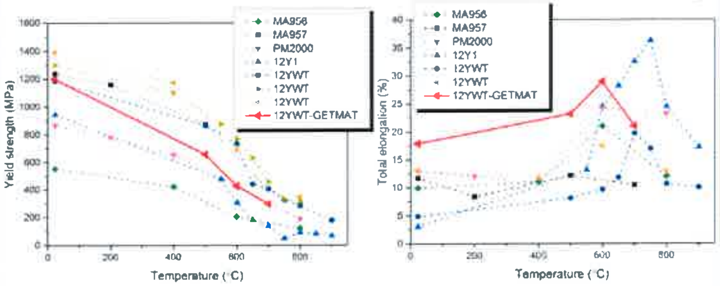
Element	Cr	W	Ti	Si	Y_2O_3	Fe
wt.%	11.59	1.87	0.22	0.1	0.23	Bal.

Microstructure @ as-received state

Chauhan et. al., J. Nucl. Mater., 2016, 468:1-8

- Bimodal microstructure
  - Heavily deformed elongated small grains (200 nm to 5 µm)
  - Deformation-free large elongated grains → partial recrystallization (up to 20 µm)
- Smallest grains are mostly oriented along <110> in extrusion direction
- Larger grains have no preferential orientation
- Complex Y-Ti-O particles : ~6 - 90 nm

Tensile properties and its comparision



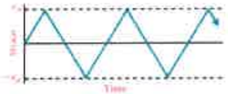
Klueh et. al., J. Nucl. Mater., 341, 2005, 103
Sokolov et. al., J. Nucl. Mater., 367-370, 2007, 213
Rahmanifard et. al., Metall. Mater. Trans A, 44, 2012, 990
Chauhan et. al., J. Nucl. Mater., 468, 2016, 1-8

- Good compromise between strength and ductility
- Characterstic total elongation peak at 600°C → change in mechanism

The improved ductility is an effect of bimodal microstructure

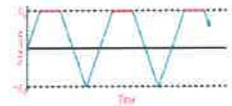
Cyclic tests at elevated temperatures

- Two temperatures (550°C & 650°C)
- Performed in air, R=-1, $\dot{\varepsilon} = 10^{-3} s^{-1}$
- Test types
  - Low cycle fatigue (LCF) or continuous cycling (CC) tests



$\frac{\Delta\varepsilon_t}{2}$ → ± 0.4% to ± 0.9%

  - Creep-fatigue tests (Hold time)



$\frac{\Delta\varepsilon_t}{2}$ → ± 0.5%

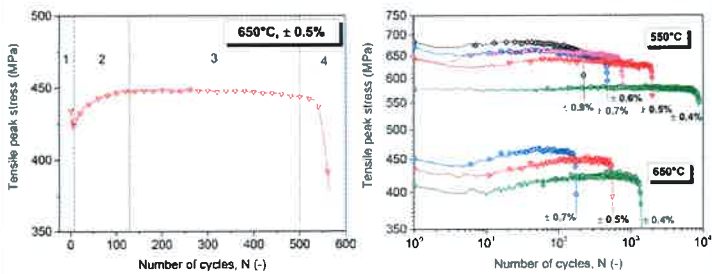
Duration → 1 & 10 min

Type → Tensile (THT)
Compressive (CHT)
Tensile-compressive (THT-CHT)

Mini specimen (7.6×2mm)

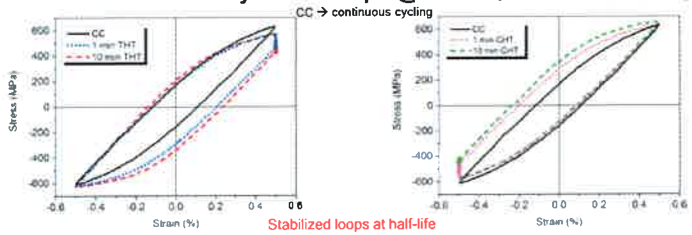
MTS servo-hydraulic UTM

Cyclic properties → LCF tests



- Four distinct stages
  1. Very brief rapid cyclic softening
  2. Gradual cyclic hardening
  3. Prolonged cyclic saturation
  4. Crack intiation and growth stage

Hold time effect on hystersis loops @ 550°C, ±0.5%



Stabilized loops at half-life

- Tensile hold time (THT)
  - Drop in the tensile peak stresses, while slightly higher compressive peak stresses
- Compressive hold time (CHT)
  - Drop in the compressive peak stresses, while slightly higher tensile peak stresses

The drop is observed independently for tensile and compressive hold time

- Hold time duration
  - Negligible effect on peak stresses
  - ⬆Hold time → ⬆Inelastic strain accumulated

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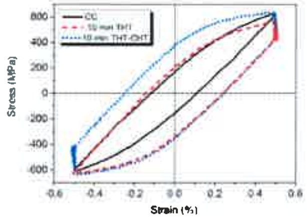
Hold time effect on hysteresis loops @ 550°C, ±0.5%

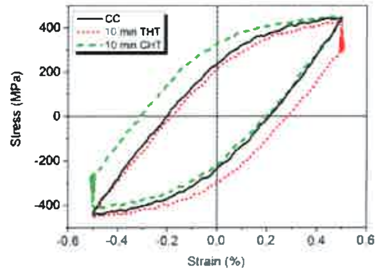


CC → continuous cycling

- Tensile hold time (THT)
  - Drop in the tensile peak stresses, while slightly higher compressive peak stresses
- Tensile-compressive hold time (THT-CHT)
  - No effect on peak stresses
  - Higher inelastic strain accumulated

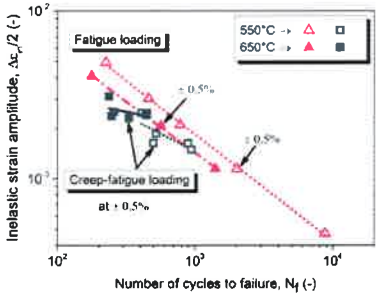
Hold time effect on hysteresis loops @ 650°C, ±0.5%

Similar observations were noticed



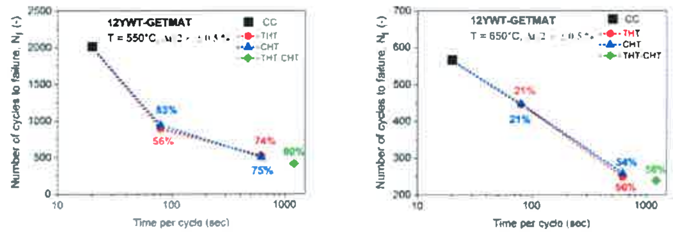
- The drop is observed independently for tensile and compressive hold time

Inelastic strain vs. Lifetime



- Creep reduces the fatigue lifetime due to increase in the inelastic strain

Hold time type effect on lifetime



- Tensile and compressive hold time result in a similar cycle life
- Lowest cycle life is observed for the hold time in both tensile and compressive direction (THT-CHT)

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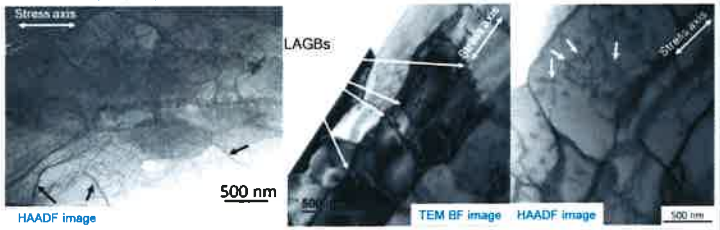
Microstructure evolution

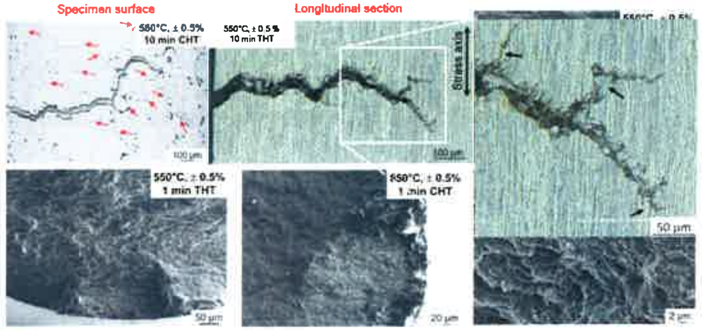
550 °C, ± 0.5 %, 10 min THT — 650 °C, ± 0.5 %, 10 min THT



- @ 550°C
  - Large grains containing high dislocation density and in-process LAGBs formation
  - Planar slip character
- @ 650°C
  - Decrease in the dislocation density
  - Large elongated grains are fractionated into smaller subgrains
  - Small grains are stable and free of dislocations
  - Pinning prevents subgrains development
  - Both planar and wavy slip characters

Oxide particles homogenity is critical

Crack initiation and propagation @ Creep-fatigue tests



- High density of surface cracks
- @ 550°C → Trangranular stage I crack initiation
- @ 650°C → Transgranular stage II crack initiation → higher oxidation near surface
- Propagation is of mixed mode type → transgranular & intergranular

Summary

- Creep-fatigue interaction in a bimodal12Cr ferritic ODS steel is investigated and presented
- Tensile hold time results in a drop in the tensile peak stresses, while slightly higher compressive peak stress and vice-versa
- Hold time duration has minor effect on peak stresses
- Hold time in both direction casues no visible effect on the peak stresses
- Microstructure shows partial stablity due to in-homogeneous distribution of oxide particles
- Transgranular stage I crack initiation at 550°C
- Transgranular stage II crack initiation at 650°C
- Mixed mode crack propagation → transgranular & intergranular

Thank you for your attention

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