Peculiarities of deformation of CoCrFeMnNi at very low temperature

A. Srinivasan¹, A. Kauffmann¹, J. Sas¹, K.-P. Weiss¹, H. Chen¹, M. Heilmaier¹ and J. Freudenberger²

¹ Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
² IFW Dresden, Dresden, Germany

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Motivation and Background

Low Temperature Deformation of CoCrFeMnNi

- Peculiarities in the low temperature deformation of CoCrFeMnNi
- Impact of lattice distortion on the movement of dislocation
- Interaction of dislocations and solutes or local chemical order
Manufacturing of CoCrFeMnNi

for reproducible materials testing and characterization

- Manufacturing:
  - arc-melting
  - homogenization (1200 °C, 72 h)
  - rotary swaging (ϕ = 1.39)
  - static recrystallization (800 °C, 1 h)

- Reproducibility
  - nominal composition (ICP-OES)
  - solid solution formation (APT + XRD)
  - recrystallization of entire microstructure (ECCI)

APT in collaboration with Dr. J.N. Wagner
Deformation behavior of CoCrFeMnNi

at very low temperatures

- Increasing yield strength as well as ductility when lowering temperature
- High work-hardening
- Deformation appears serrated at 4.2 K
Work-hardening at very low temperatures

Formation of a plateau at cryogenic operating conditions

- 4.2 K, determined from the maxima
- 77 K
- 295 K

\[
\frac{d\sigma_t}{d\varepsilon_t} = \sigma_t
\]
Work-hardening at very low temperatures

- Limited twin formation at deflection point
- $\varepsilon$-martensite was not observed

![Image of tensile direction with scale bar 10 μm]

Graph showing the relationship between stress ($\sigma_t$) and strain ($\varepsilon_t$) at different temperatures (295 K, 77 K, 4.2 K). The graph indicates that $d\sigma_t/d\varepsilon_t = \sigma_t$ at these temperatures, determined from the maxima.
Serrated Plastic Flow

Origin of serrated plastic flow

- Serrations at cryogenic temperatures have been seen in many metals previously.
- Lack of coupling to He bath due to heat of deformation results in adiabatic heating
- Intrinsically driven by avalanche slip events and deformation twinning

4.2 K

\[ \sigma_e / \text{MPa} \]

\[ \varepsilon_e / \% \]
Serrated Plastic Flow

Tensile tests in different cooling media

3 \cdot 10^{-6} \text{ s}^{-1}

4.2 \text{ K},
emerged in He
(132 drops)

8 \text{ K},
He gas stream
(151 drops)

4.2 \text{ K},
emerged in He
(132 drops)

8 \text{ K},
He gas stream
(151 drops)

Tensile tests in different strain rates

8 \text{ K}

6 \cdot 10^{-7} \text{ s}^{-1}
(149 drops)

3 \cdot 10^{-6} \text{ s}^{-1}
(151 drops)

1 \cdot 10^{-5} \text{ s}^{-1}
(30 drops)

Tensile tests in different gauge volumes

3 \cdot 10^{-6} \text{ s}^{-1}
8 \text{ K}

1 \cdot 10^{-5} \text{ s}^{-1}
8 \text{ K}

3.10^{-6} \text{ s}^{-1}
8 \text{ K}

1.10^{-5} \text{ s}^{-1}
8 \text{ K}

d = 2\text{mm}
(317 drops)

d = 4\text{mm}
(151 drops)
Conclusions

Low Temperature Deformation of CoCrFeMnNi

- Extent of influence of twinning in the plateau initiation is questionable considering the twin density at that point.
- Serrated plastic flow seems to be influenced by coupling with the cooling media, but extent of intrinsic influence needs to be verified as well.
Outlook

Low Temperature Deformation of CoCrFeMnNi

- Interrupted tensile tests at various points of the plateau
- Estimate the extent of intrinsic behavior involved in the serrations
- The cause for the absence of ε-martensite needs to be understood
Thank you for your kind attention.

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