Project 50: Understanding Influence of Heat-Treatment on Serrated Yielding in a Ni Superalloy and Hot Compression of Magnesium Alloys

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CANFSA
Center for Advanced Non-Ferrous Structural Alloys
An Industry/University Cooperative Research Center

Industrial Relevance:

- **Problem:** Ni-based superalloys exhibit serrated yielding, which results in increased strain at constant stress. Novel Mg alloy dynamic recrystallization kinetics are not well understood.
- **Objective:** Understand the origins of localized deformation in wrought and powder Ni-based superalloys accompanying serrated yielding and determine/control the mechanisms. Perform dynamic recrystallization studied on novel Mg alloys.
- **Benefit:** Improving the mechanical properties of Ni-based superalloys can lead to better performance and more efficient turbine engines. Improve understanding of processing windows of novel Mg alloys.

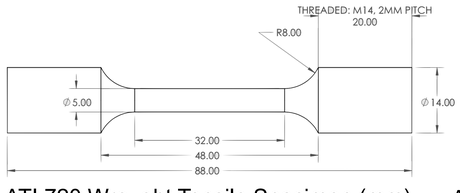
High pressure turbine disk, 50cm diameter
https://jetartaviationshop.co.uk/product/raf-sepecat-jaguar-aircraft-rolls-royce-adour-jet-engine-hp-turbine-disc-aviation-art/

Approximately 1m diameter
R.J. Mitchell, et al. Proc. Int. Symp. Superalloys. (2008)

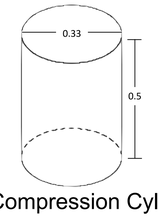
Methods:

ZwickRoell Kappa DS 50kN
https://www.zwickroell.com/products/static-materials-testing-machines/creep-testing-machines/kappa-ds/

Gleeble 3500
https://www.gleeble.com/products/gleeble-systems/gleeble-3500.html

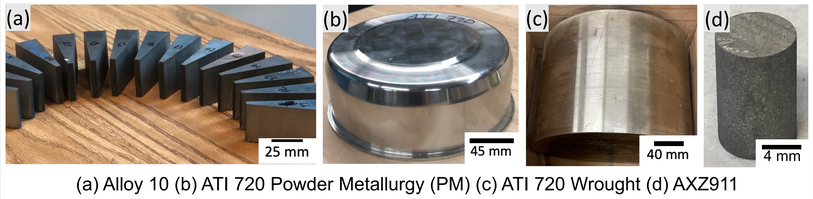


ATI 720 Wrought Tensile Specimen (mm)



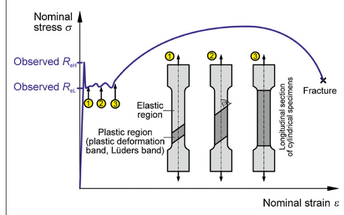
AXZ911 Compression Cylinder(in)

Material:



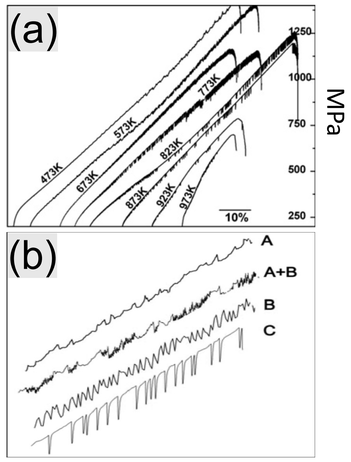
(a) Alloy 10 (b) ATI 720 Powder Metallurgy (PM) (c) ATI 720 Wrought (d) AXZ911

Ni Serrated Yielding Background:



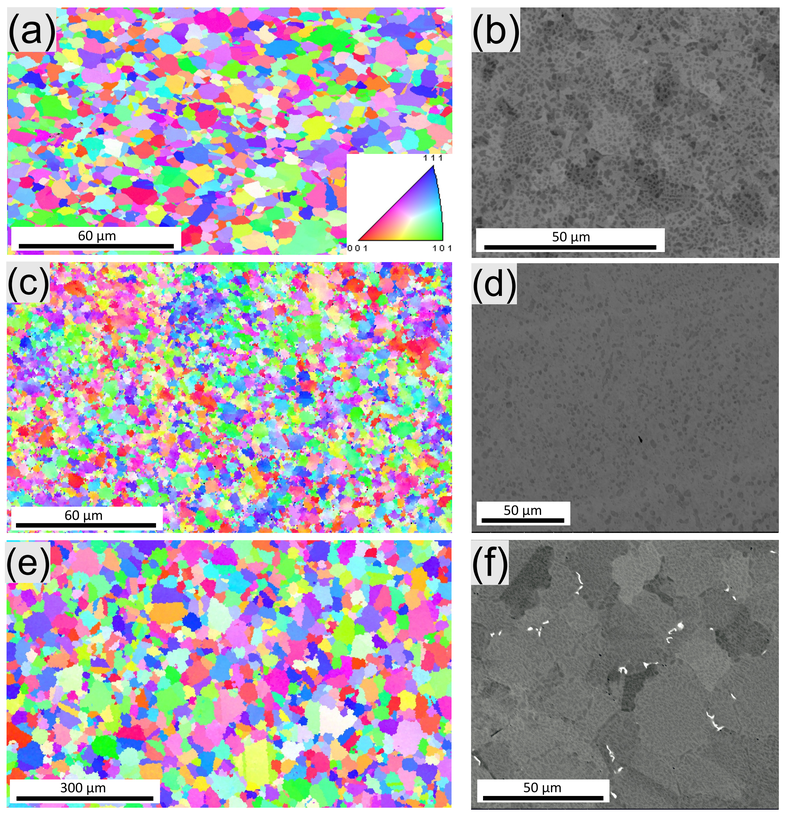
Yield point phenomenon common behavior
R. Schwab, et al. Acta Mater. 61 (2013)

- Type A: Low temperature response resulting from propagation of Lüders bands.
- Type B: Elevated temperature and low strain rate response caused by shear band propagation due to nucleation sites in neighboring grains.
- **Type C:** High temperature and quasistatic or lower strain rate response resulting from dislocation unlocking from the solute atmosphere.



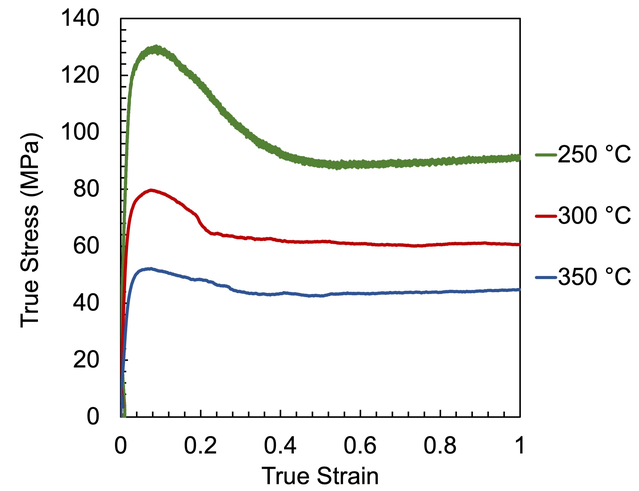
Serrated Yielding Responses
S.A. Nalawade, et al. Scr. Mater. 59 (2008)

Ni Serrated Yielding Recent Progress:



(a) ATI 720 PM IPF in radial direction (b) BSE of ATI 720 PM (c) ATI 720 Wrought IPF in radial direction (d) BSE of ATI 720 Wrought (e) Alloy 10 IPF in radial direction (f) BSE of Alloy 10

Mg Compression Recent Progress:



True stress vs. true strain for AXZ911, constant displacement rate (~8 mm/s)

Future Work:

Ni Serrated Yielding

1. Perform tensile testing to determine temperature/strain rate regimes for onset of serrated yielding.
2. Utilize Modeling of J.D. Baird and C.L. Hale to determine the activation energy and responsible mechanisms for serrated yielding:
   a. $Q = -R\left[\frac{\Delta \ln \dot{\varepsilon}}{\Delta \frac{1}{T}}\right]_{\Delta\sigma,\varepsilon}$, (J. D Baird)

   b. $\varepsilon_C^{m+\beta} = K\dot{\varepsilon}\exp\left(\frac{Q}{RT}\right)$, (C. L Hale)
      - Interstitial solutes ($0.5 \le m + \beta \le 1$)
      - Substitutional solutes ($2 \le m + \beta \le 3$)

Magnesium Compression

1. Continue compression testing in quasi-strain control to aid in modeling.
2. Characterize as-received and post-deformation microstructures.

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