Development of Advanced High-Temperature Ni-Base Superalloys for Fossil Energy Applications

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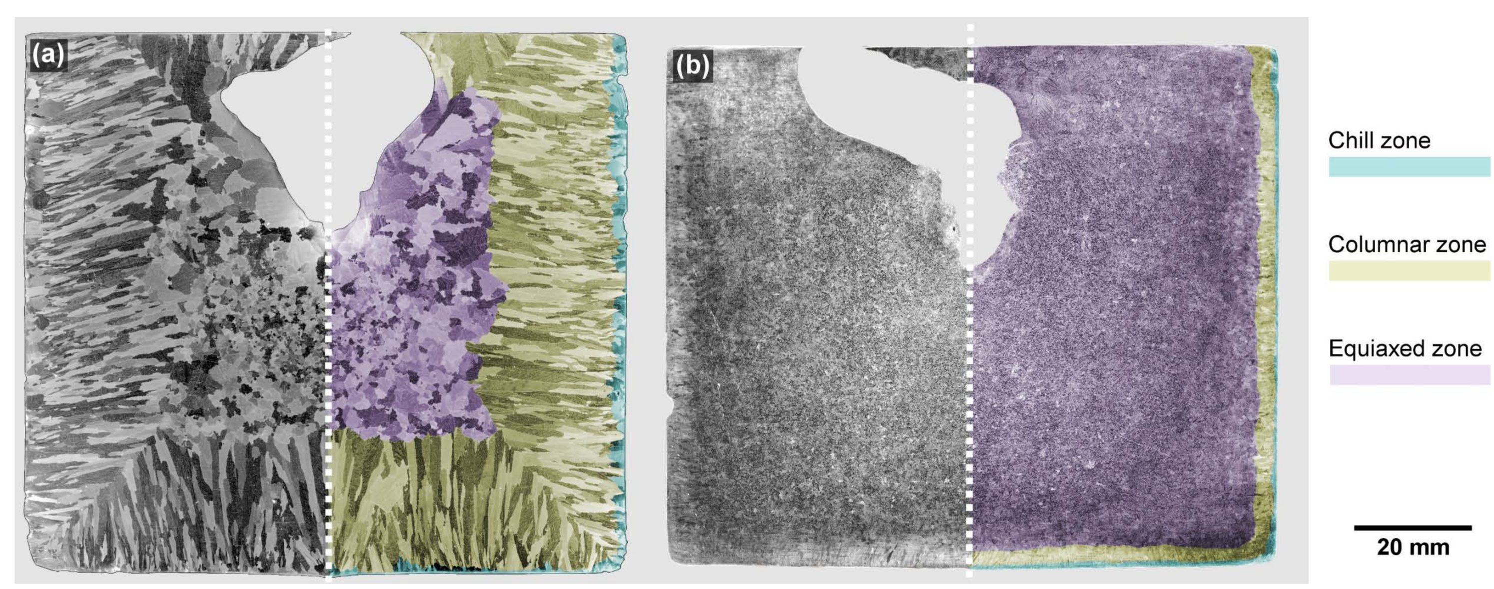
Introduction

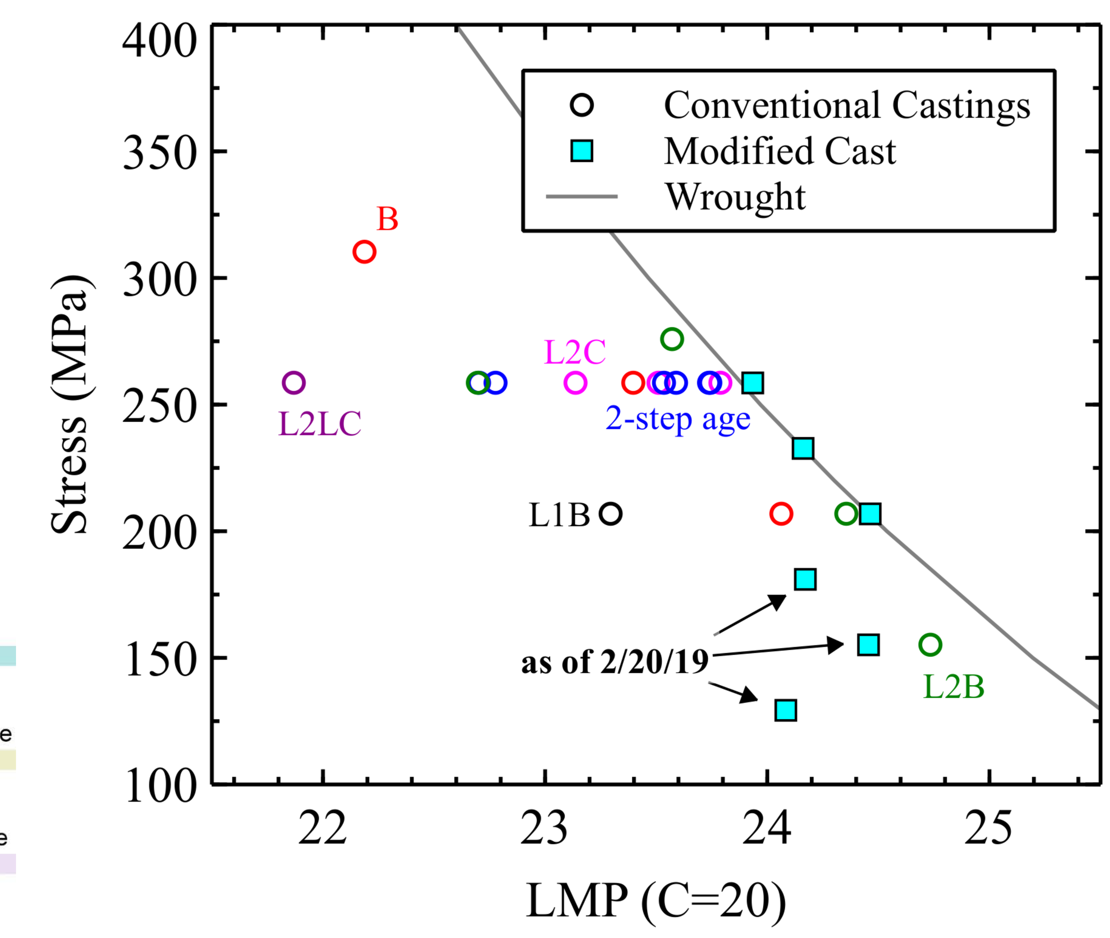
NETL utilizes an integrated approach that leverages computational materials engineering, manufacturing at scales that readily translate to industrial practice and performance assessment at condition to develop alloys that can improve the performance of the existing fleet and enable advanced fossil energy systems.

Ni-based superalloys are widely used in applications that require high strength and toughness at elevated temperatures. Several approaches are investigated at NETL to advance research in Ni-based alloys from modifications of thermo-mechanical processing, improvement of commercial alloys to the development of new concepts.

Casting

- A modified casting route was developed for commercial alloy 740H that leads to a more homogeneous grain size distribution (b) compared to (a) as well as a better repartition of the grain boundary carbides.
- The modified casting showed improved creep performance as compared to several conventional castings.
- To date, the Larson-Miller Parameter curve for the modified casting is on track to overlap with the wrought processed material.

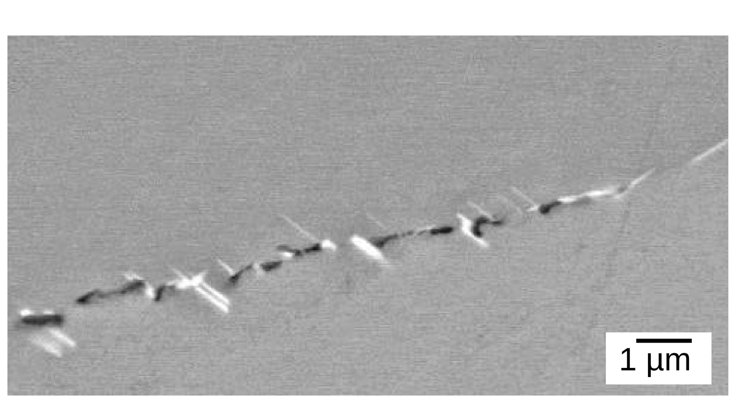


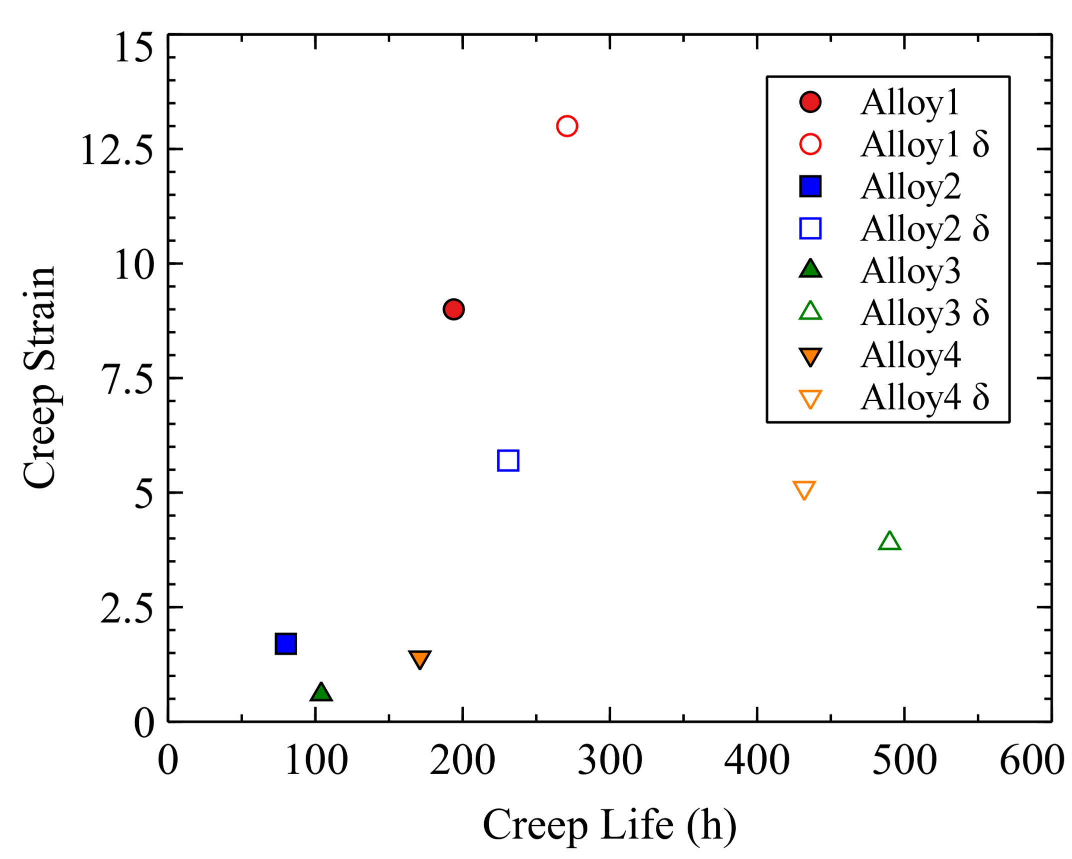


Larson-Miller Parameter plot for 5 different conventional castings, the modified casting version and the wrought product.

Grain Boundary Design

- Precipitation of phases at the grain boundaries to increase their strength or resistance to shear deformation.
- A δ (delta) aging treatment was developed for a commercial Ni-based superalloy which resulted in the formation of δ precipitates across the grain boundaries (grain boundary stitching).
- The aging treatment resulted in improvements in creep strain and life.

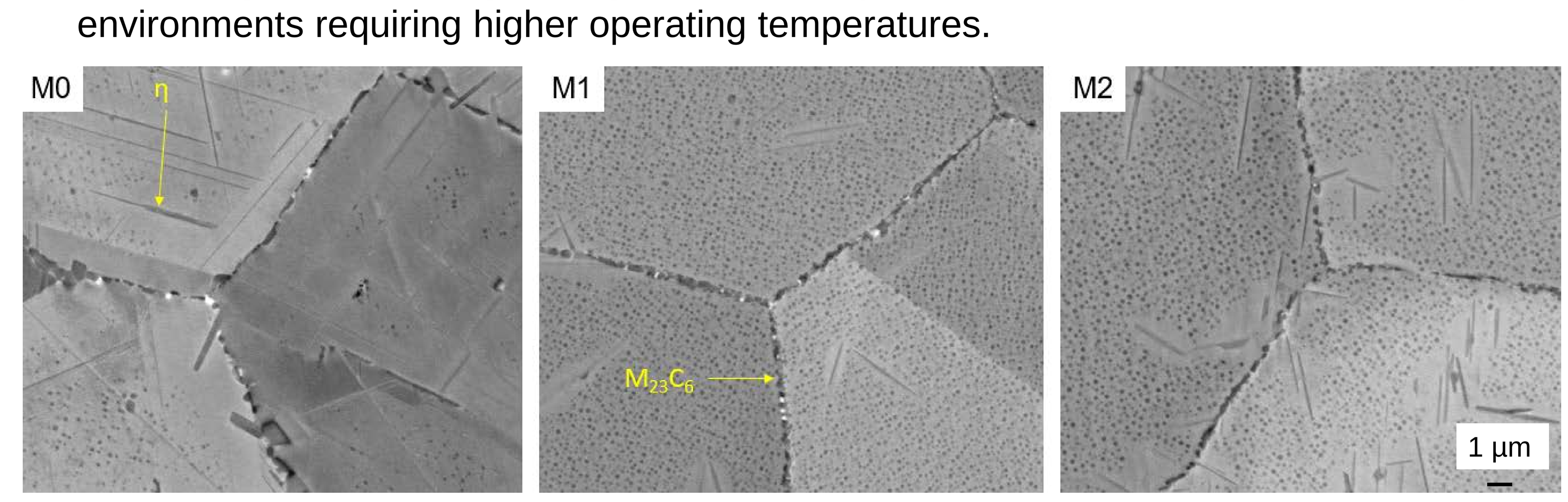




Creep strain vs creep life for variants of a commercial Ni-based superalloy with a conventional aging treatment or a δ aging treatment.

Strengthening & Stability

- Investigations aiming at modifying the compositions of commercial Ni-based superalloys to improve their thermo-mechanical properties are conducted using various approaches.
- The γ' precipitate strengthening phase can be controlled with respect to its size, fraction and stability (coarsening).
- The formation of undesirable phases after extended time at temperature observed in several commercial alloys can be minimized as shown in the SEM micrographs below.
- Controlling both strengthening and stability enables the use of the alloys in environments requiring higher operating temperatures.

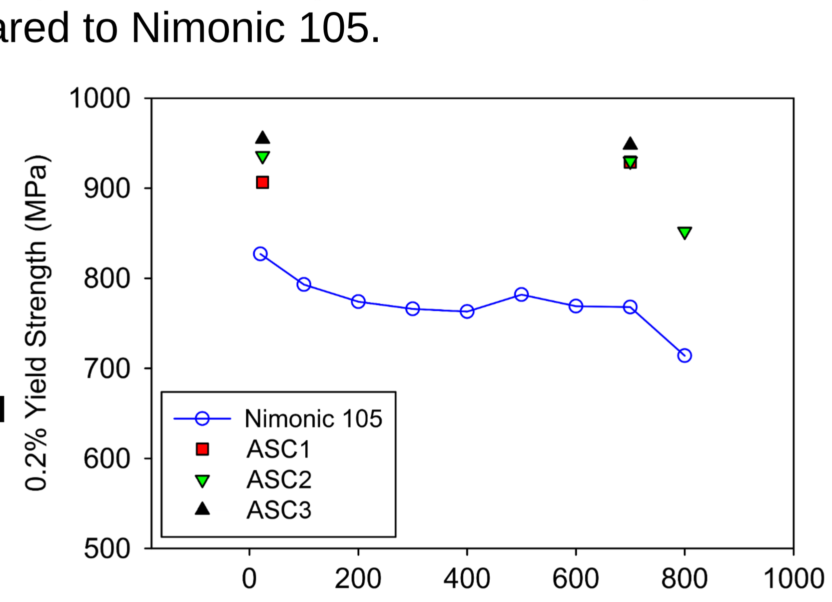


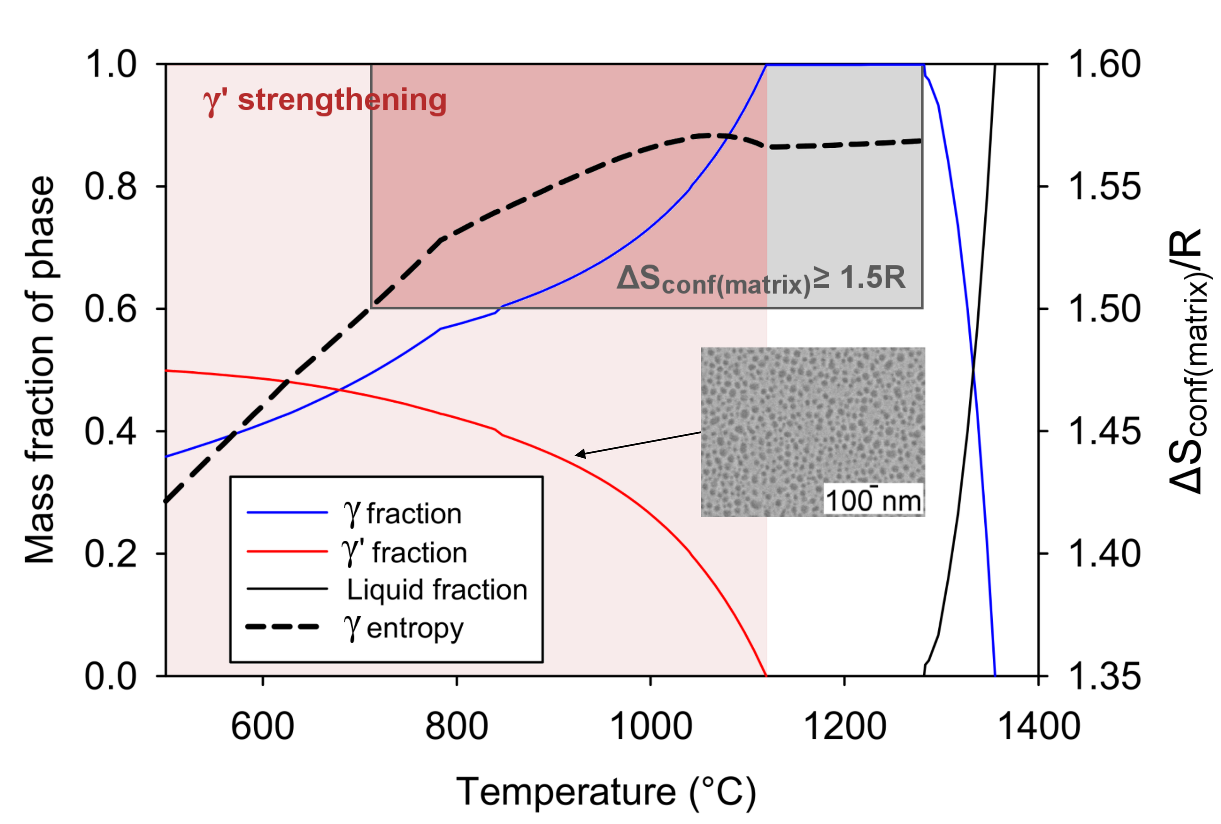
5000h / 800C Exposure; nominal alloy 263 (M0) and modified versions (M1, M2).

Alternate Concepts

- A Ni-based superalloy was designed with a controlled γ/γ' lattice misfit, nano-sized γ' precipitates and using the entropy concept to obtain a high-entropy γ matrix around the operating temperature of the alloy.
- The alloys are showing improved strength when compared to Nimonic 105.

► Yield strength of the ASC alloys compared to commercial alloy Nimonic 105.





Predicted phase diagram from ThermoCalc showing precipitation of the γ' strengthening phase and the entropy of the γ matrix.

Laboratory

Acknowledgements

This work was performed in support of the US Department of Energy's Fossil Energy Crosscutting Technology Research Program. The Research was executed through the NETL Research and Innovation Center's Advanced Alloy Development Field Work Proposal. Research performed by Leidos Research Support Team staff was conducted under the RSS contract 89243318CFE000003.

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NATIONAL ENERGY TECHNOLOGY LABORATORY

2019 Crosscutting Annual Review Meeting
Pittsburgh April 10th, 2019, Pennsylvania

U.S. DEPARTMENT OF ENERGY