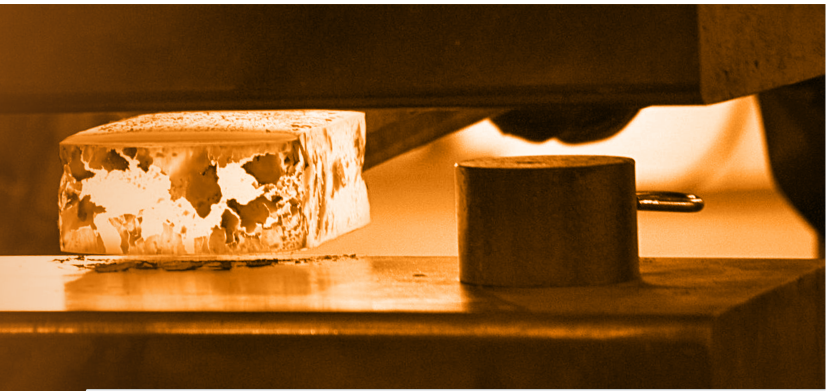
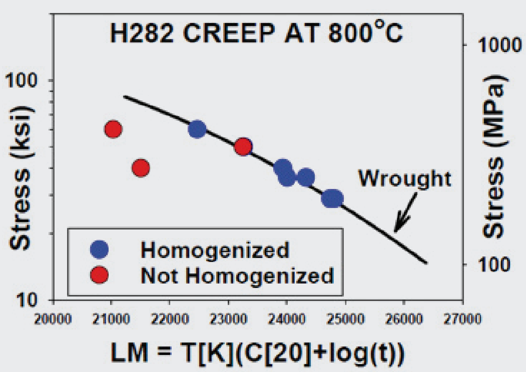
NETL's

Advanced Alloy Development Research



NETL utilizes an integrated alloy development approach that leverages computational materials engineering, manufacturing at scale, and performance assessment at condition to develop alloys solutions to enable advanced technologies.

NETL has demonstrated and deployed alloys with improved performance capabilities for energy applications, aerospace, defense, and bio-medical applications. NETL has also implemented technologies to improve melting and casting practices.



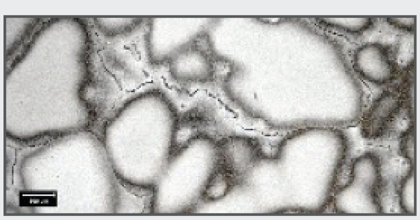
Creep properties of alloy H282 in cast and wrought form. Properly homogenized casting have equivalent properties to wrought alloy.

NETL's Award Winning Computational Homogenization Heat Treatments Routine

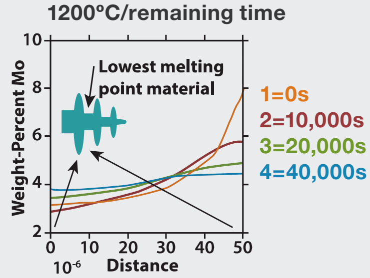
NETL has developed a computational routine to homogenize castings and ingots. The approach uses CALPHAD and simulations of the diffusion of alloying elements based on measured or calculated dendrite arm spacing from a casting to devise multi-step heat-treatments to homogenize alloy castings. The NETL methodology won an R&D 100 award in 2016.

The technology was developed to demonstrate that thick wall castings could be manufactured from typically wrought gamma-prime strengthened Ni-base superalloys. NETL demonstrated that through proper homogenization, cast alloys could be produced that have equivalent creep properties to the wrought versions of the alloy. This was key in enabling Advanced Ultra-Supercritical Steam (A-USC) turbine technology (A-USC). In support of the A-USC program, NETL designed heat-treatments of subsequently larger ingots and castings that were produced at a variety of commercial casting and heat-treating facilities. This culminated with the design of a heat-treatment for an ½ valve body 18,000-pound demonstration casting of a precipitation hardened superalloy. One aspect of the NETL routine, is that heat-treatments can be tailored to meet existing furnace capabilities available at the heat-treating facility.

AS-CAST



1100°C/10,000x+
1200°C/remaining time



HOMOGENIZED

REFERENCE:

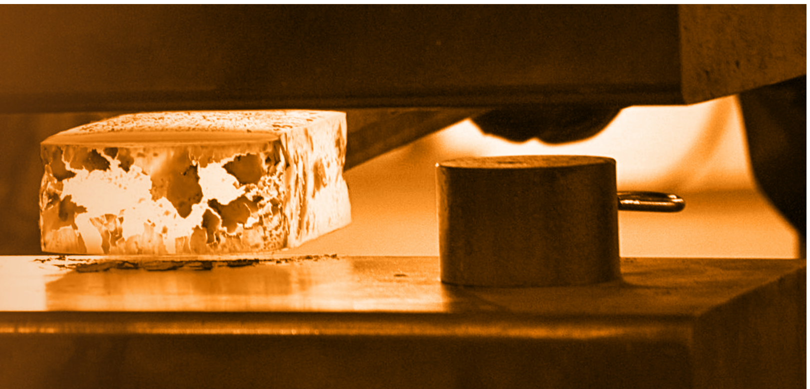
Jablonski, P.D. and J.A. Hawk, Homogenizing Advanced Alloys: Thermodynamic and Kinetic Simulations followed by Experimental Results. Journal of Materials Engineering and Performance, 2017. 26(1): p. 4-13.

www.netl.doe.gov

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

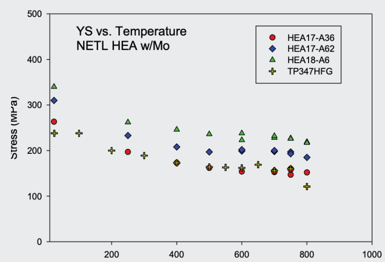
NETL's

Advanced Alloy Development Research



High Entropy Alloys

NETL austenitic HEAs have been designed and manufactured for corrosion and oxidation resistance, mechanical response, lower cost, and increased manufacturability. NETL HEAs have superior corrosion resistance than Alloy C276, comparable oxidation to Alloy 282, and higher tensile strength than Alloy 347HFG.



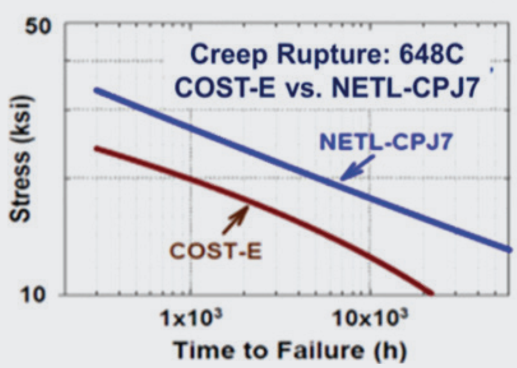
Yield stress versus temperature for NETL HEA alloys compared to fine grained type 347H (TP347HFG) stainless steel. HEA properties measured from hot rolled plate from 15 pound vacuum induction melted ingots.

9-12 Cr Steels Development

NETL-CPJ7 and NETL-JMP Ferritic-Martensitic Steels

NETL has developed a series of Ferritic-Martensitic steels with improved creep performance compared to current advanced 9-12Cr steels (alloy Cost-E). The current advanced technology can endure about 600°C in high pressure steam turbines. NETL developed 9-12Cr steels (NETL-CPJ and NETL-JMP) that may extend service of this power plant alloy class to 650°C. These steels will be more durable in flexible mission profiles and result in lower materials costs of advanced energy systems.

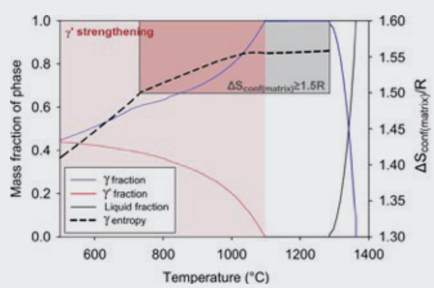
US Patents: 9,181,597 & 9,556,503



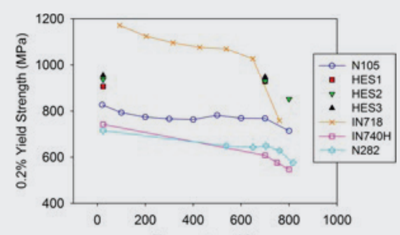
Creep @ 648°C of NETL-CPJ7 compared to COST-E

Advanced Superalloy Concepts

High Entropy Alloy concepts are used to design superalloys with a more stable matrix. NETL is developing wrought and cast alloys for high-temperature (>800°C) applications.



Ni-base superalloys were designed with the coexistence of precipitation strengthening and high entropy matrix suitable for high temperature application.



Yield stress for NETL HES superalloys compared to conventional superalloys.

REFERENCES:

M. Detrois, P.D. Jablonski, S. Antonov, S. Li, Y. Ren, S. Tin, and J.A. Hawk, "Design, Phase Stability and Mechanical Properties of a Precipitate-strengthened High-entropy Superalloy," J. Alloys & Compounds, Vol. 792 (2019) 550-560 (On-line 6 April 2019: https://doi:org/10.1016/j.jallcom.2019.04.054).

M. Detrois, S. Antonov, S. Tin, P.D. Jablonski, and J.A. Hawk, "Hot Deformation Behavior and Flow Stress Modeling of a Ni-based Superalloy," Materials Characterization, 157 (2019) 109915 (On-line First 4 September 2019: https://doi.org/10.1016/j.matchar.2019.109915).

M.C. Gao et al, "High Entropy Alloy Development for Fossil Energy Applications," https://netl.doe.gov/node/8774.

David Alman–*Associate Director*

Materials Engineering & Manufacturing Directorate
david.alman@netl.doe.gov

Marisa Arnold-Stuart–*Supervisor, Structural Materials Team*

Materials Engineering & Manufacturing Directorate
marisa.arnold@netl.doe.gov