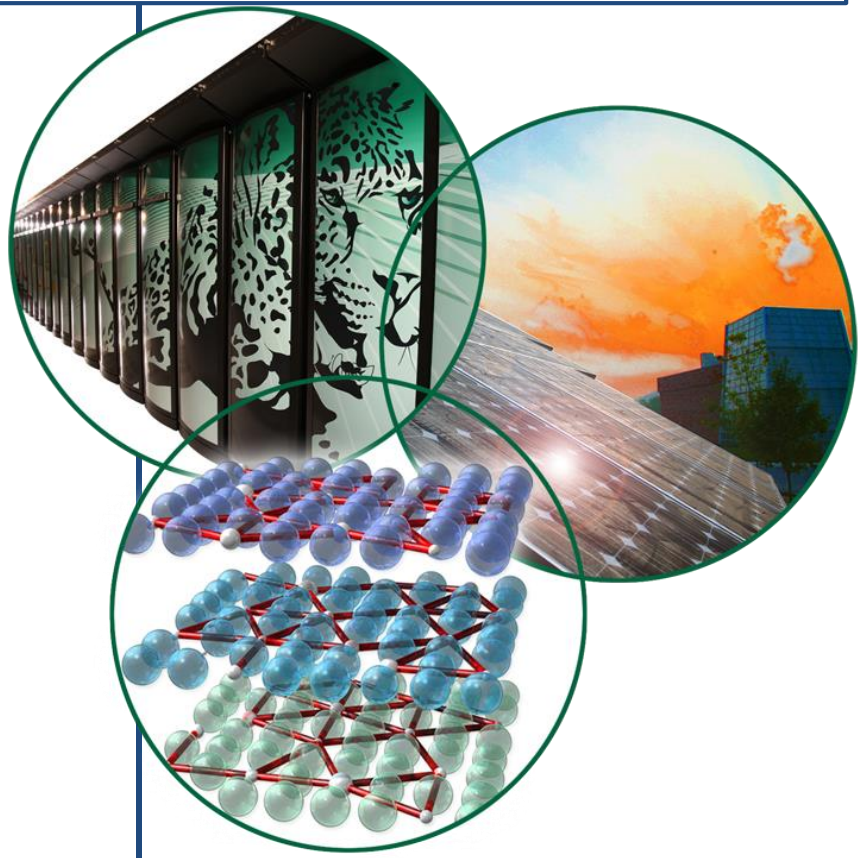
Properties of Advanced Ni-Based Alloys for Ultra Supercritical Steam Turbines



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U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

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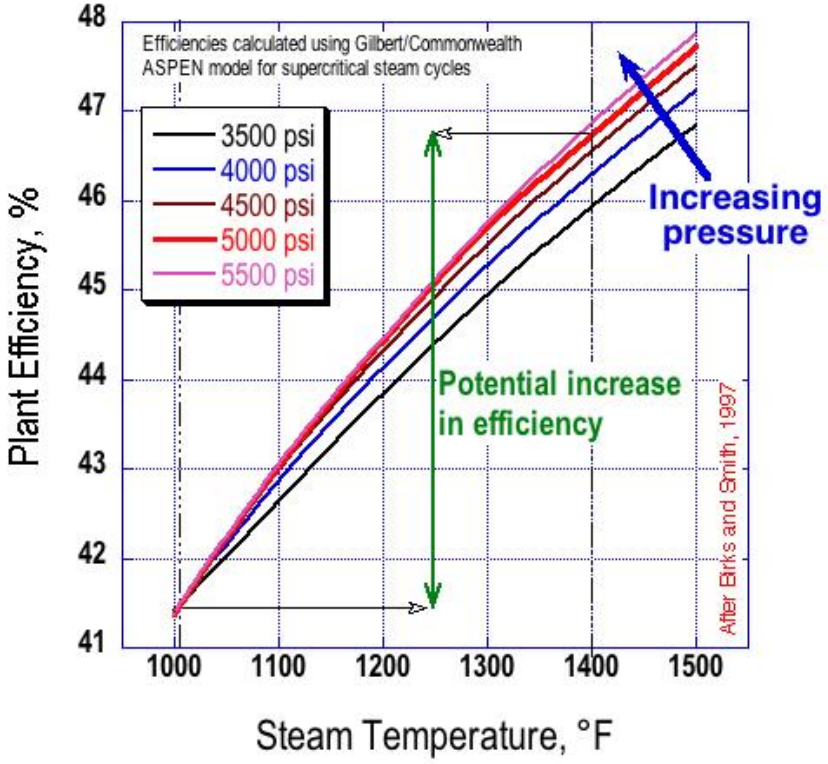
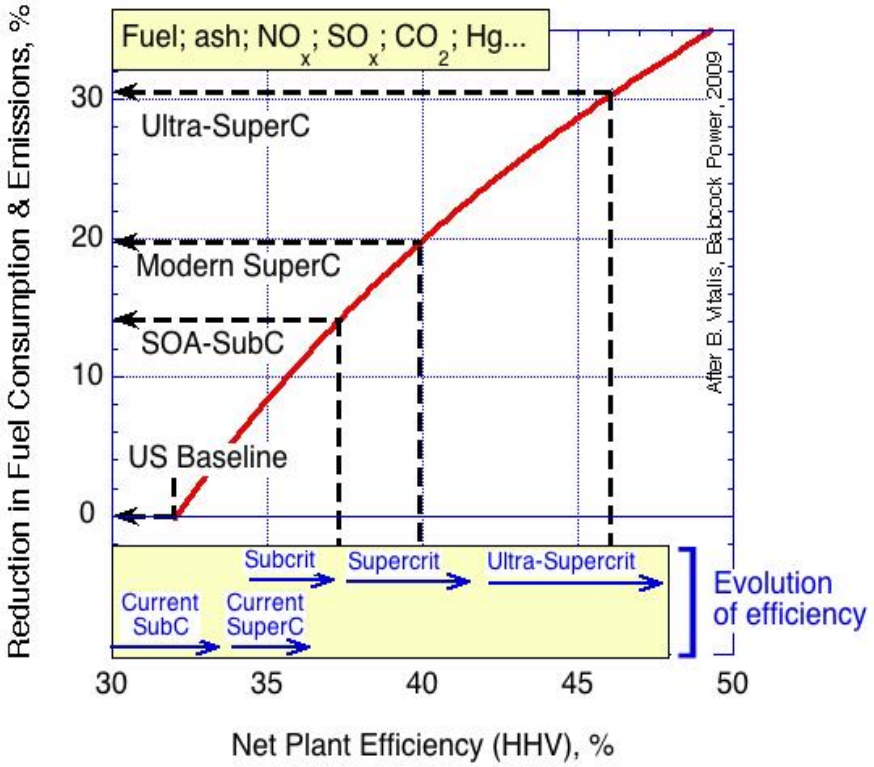
Increasing Steam Temperature and Pressure Increases Thermal Efficiency and Decreases Emissions for Advanced UltraSuperCritical (A-USC) Steam Technology





"Least Regret" Strategy for CO_2 Reduction (Viswanathan and Shingledecker, EPRI Conf., Santa Fe, NM, Aug. 2010)

Testing and Characterization of Large Triple-melt forging of Haynes 282 alloy

Primary & Secondary Melting

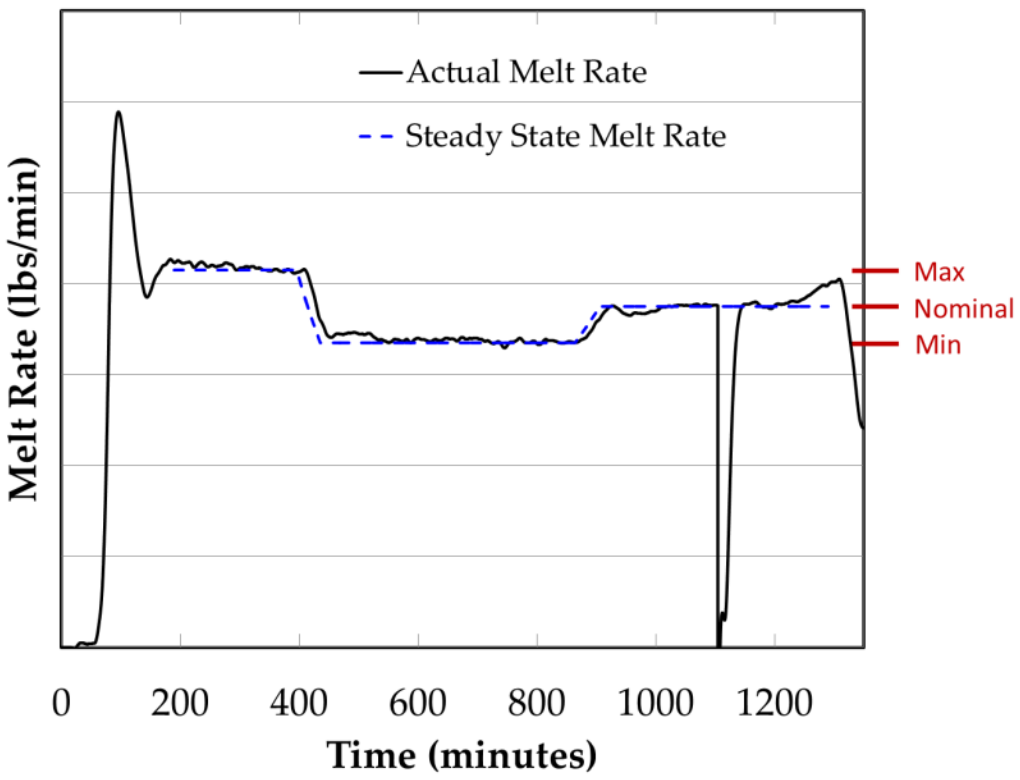
VIM Electrodes

- Two 457mm (18”) DIA electrodes were melted and cast by vacuum induction
- Electrodes were annealed before remelt to minimize stresses

ESR Ingode

- Electrodes were electro-slag remelted to 559mm (22”) DIA ingodes
- No events observed in ESR
- Slow cooled in insulated can and annealed to minimize residual stresses

Varying Melt-Rate VAR Trial



- First VIM-ESR ingot remelted by vacuum arc remelt to 610mm (24”) DIA ingot
- Custom profile used with three melt rates and an intentional 60-second power interruption to determine the effect of segregation
  - If determined to be segregation-free, VAR fixed practice is established with allowed limits being the Min/Max melt rates evaluated

Rotor Forging

- Goal #1 – 45” diameter x 8-10” thick
- Goal #2 – Grain size ASTM 6 or finer (uniform structure)
- Alloy 282® billet from SMC was forged into a pancake using three upsets
- Forging was then aged using two-step heat treat: 1010°C/2hr/AC + 788°C/8hr/AC

Start Bingot → **1st Upset** → **2nd Upset** → **3rd Upset**

Final Dimensions:

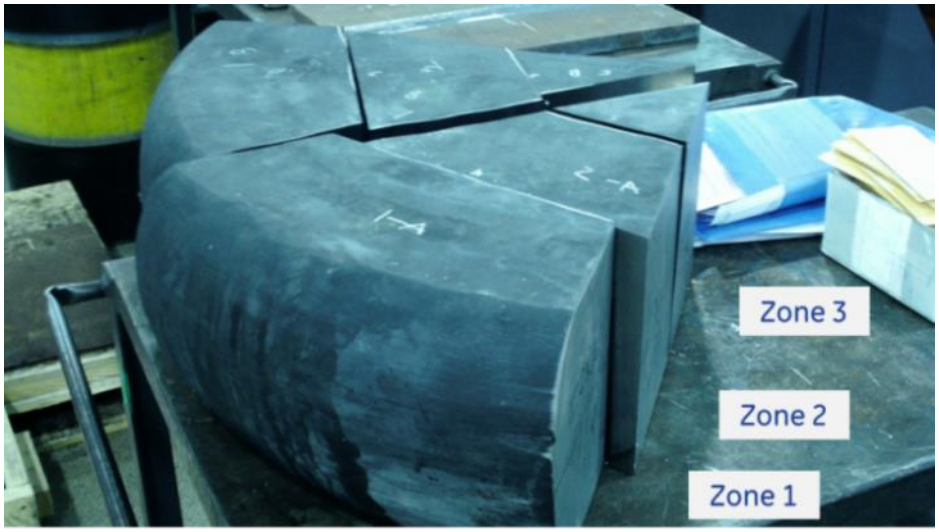
Diameter (Top): 44”

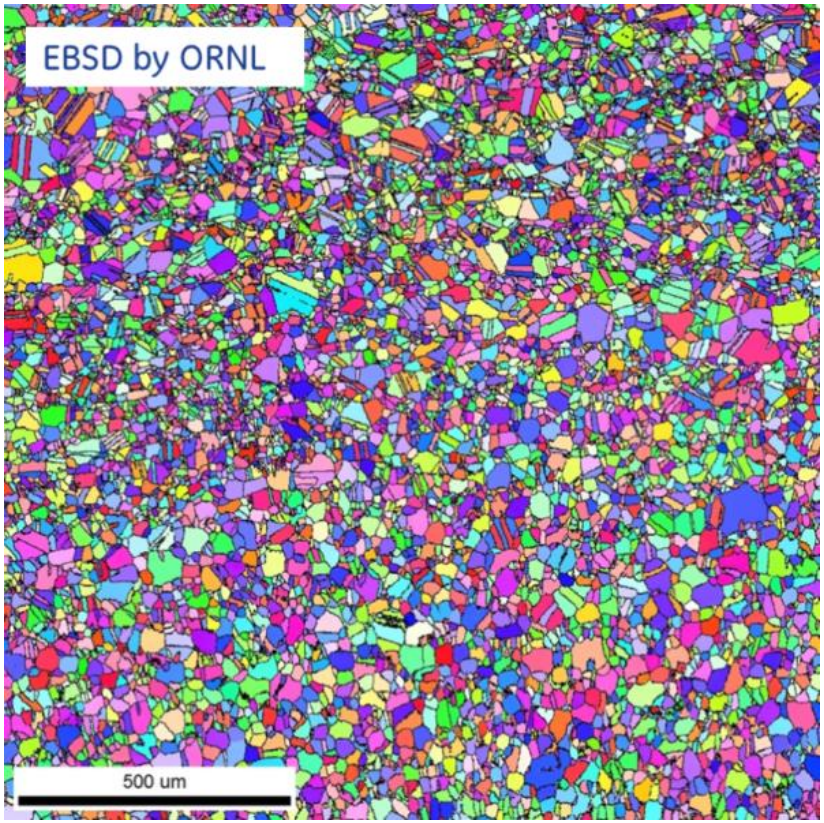
Diameter (Bulge): 49.5”

Thickness: 9.5”

Testing & Evaluation

- The forging was sectioned into zones for property evaluation
- Microstructure was determined to be fine and uniform with:
  - Typical Grain Size: ASTM 8-9
  - Grain Size ALA: ASTM 4
- No texture observed

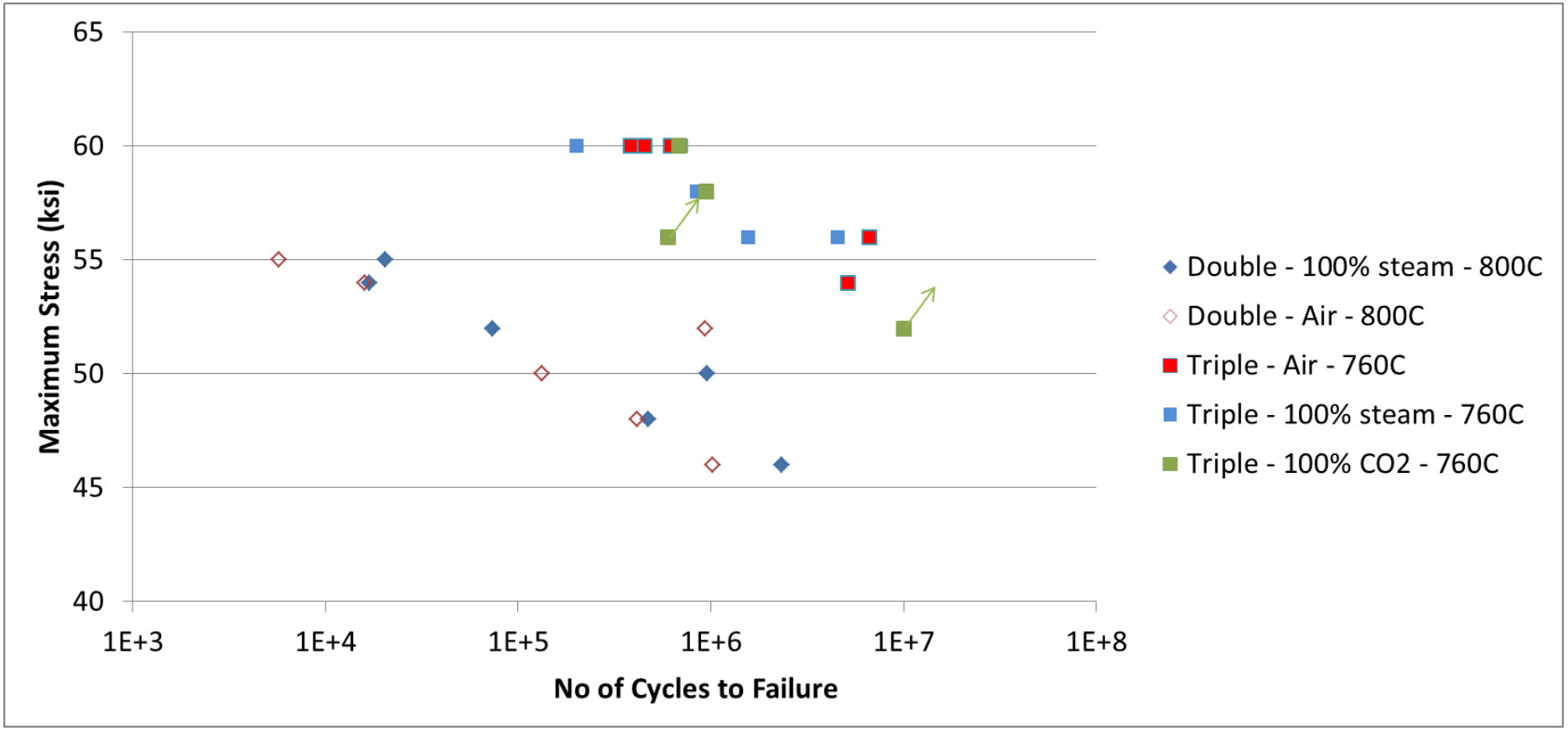




HCF testing of forged Haynes 282 in CO_2 environment at 760°C

- Testing began in May on remaining HCF specimens from steam effects testing
- Preliminary results show little effect of CO_2 on HCF life
- More forged Haynes 282 is needed for complete testing and to confirm the above results

CO_2 environment testing



- No effect

DEVELOPMENT OF SAND CASTING PROCESS

- H282 ingot used as melt stock
- Same melt practice developed for centrifugal casting used
- Reactive element and timing concerns
- Mold purging
- Simulation

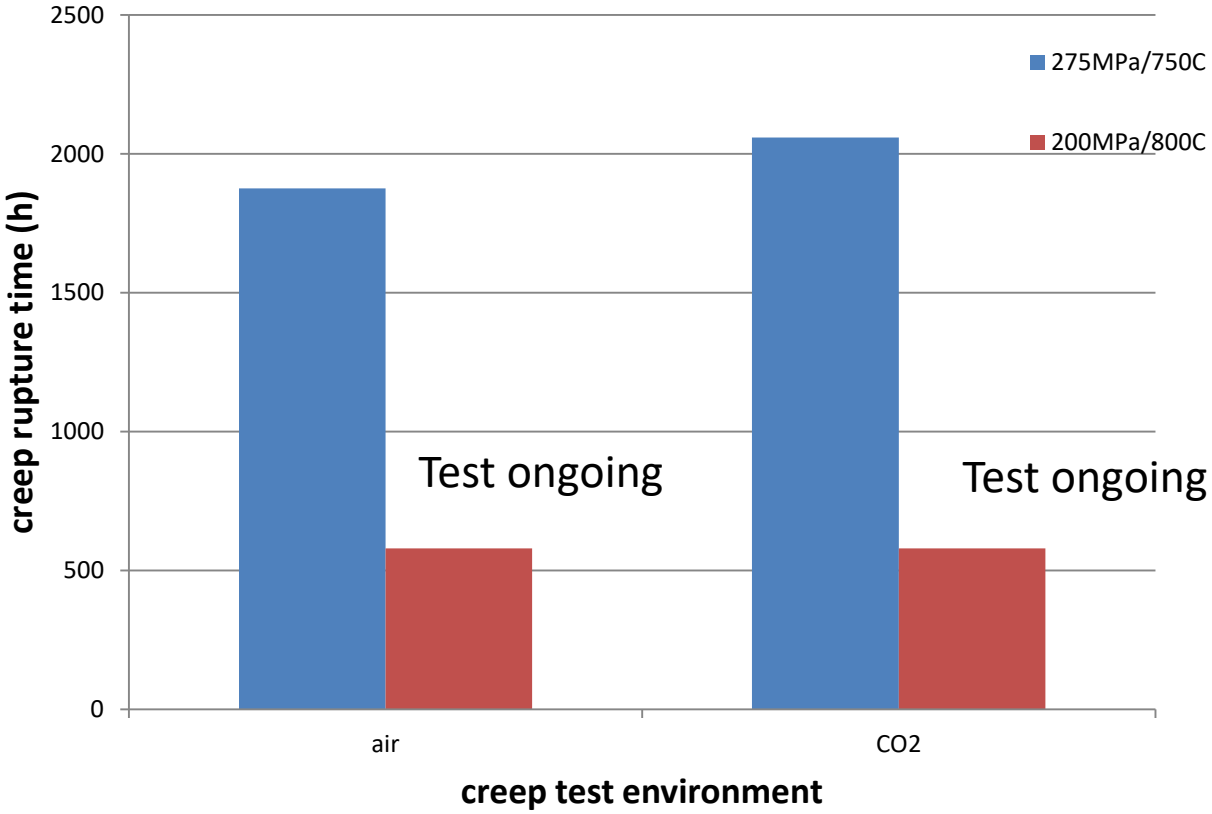
DEVELOPMENT OF SAND CASTING PROCESS

- Cast on coupons removed
- SDAS analysis for solution heat treatment
- Solution and Age heat treatment of casting

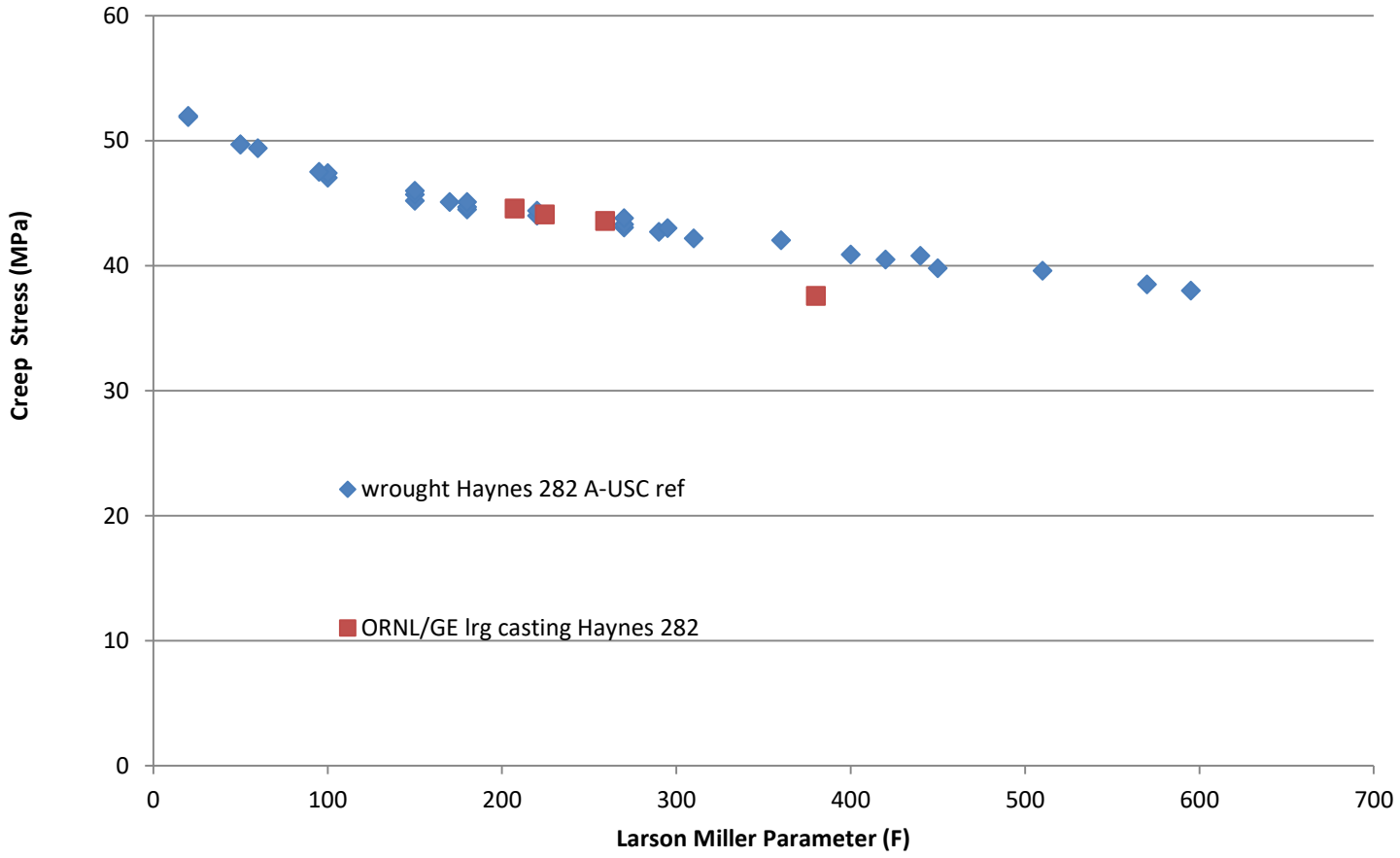
Creep testing of Cast Haynes 282 alloy at 750^{o}C in CO_2

- Creep testing in air and CO_2 at 275MPa and 750^{o}C, and at 200MPa at 800^{o}C
- At 750^{o}C, specimen failed after 1876h in air, but last for 2059h in CO_2

Creep Data on Cast Haynes 282 Alloy is as good or better in CO_2 than in air



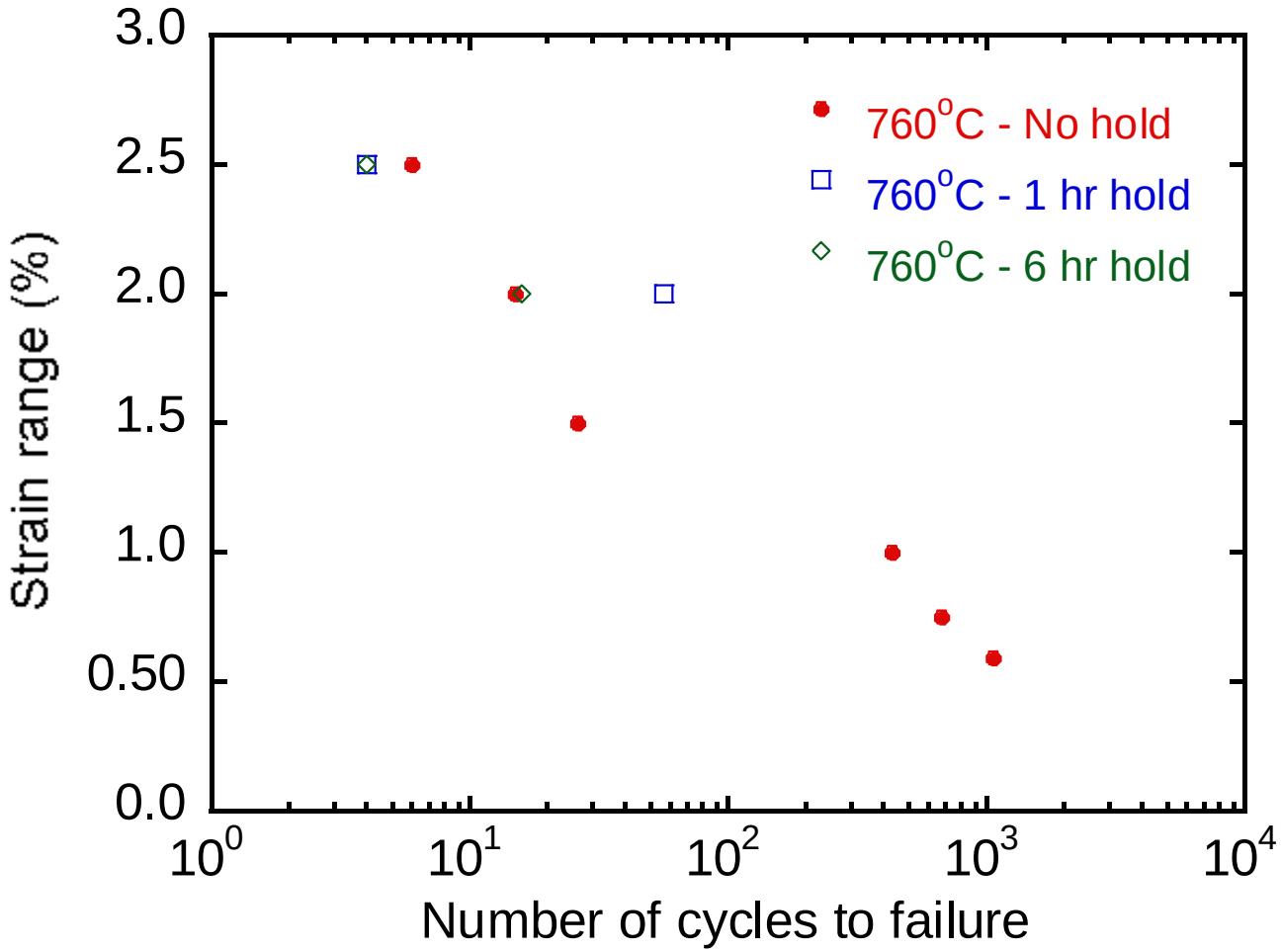
ORNL/GE Creep-Rupture of Large Sand Casting of Haynes 282 alloy (tests have ruptured)



New LCF testing of Large Casting of Haynes 282 Alloy

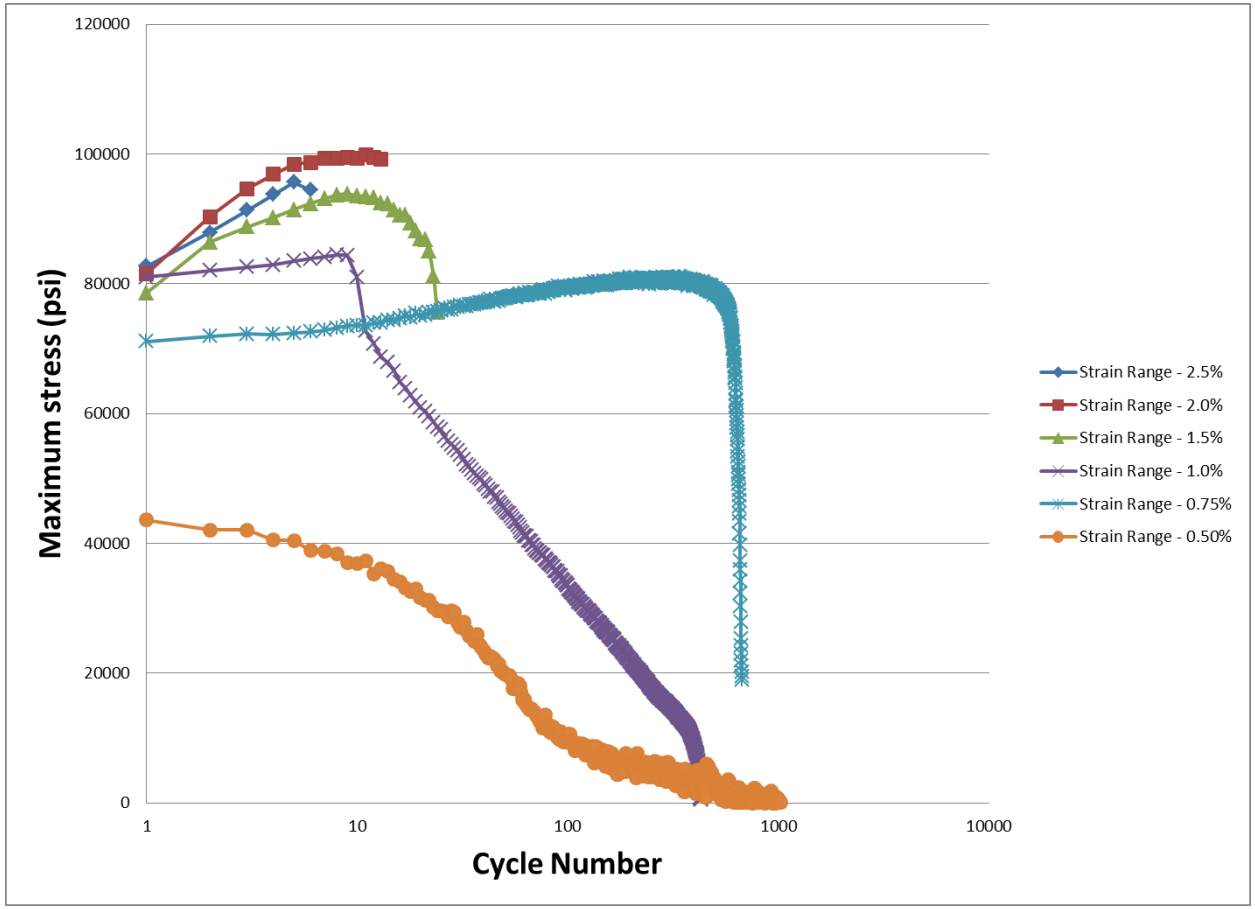
- LCF testing of 10 specimens at 760^{o}C to generate baseline curve
- Creep-fatigue testing at the same temperature with hold times of 1h and 6h

Summary slide for LCF testing for cast Haynes 282 at 760°C



- No significant detrimental effect of hold time in the conditions tested.
- Note: Hold time applied at maximum tensile strain.

Maximum stress evolution in specimens with no hold time



- Two types of behavior seen that may be indicative of ease of crack formation in the cast structure
- Early crack formation leads to graceful failure