CRADA NFE-08-01671 – Materials for Advanced Turbocharger Design

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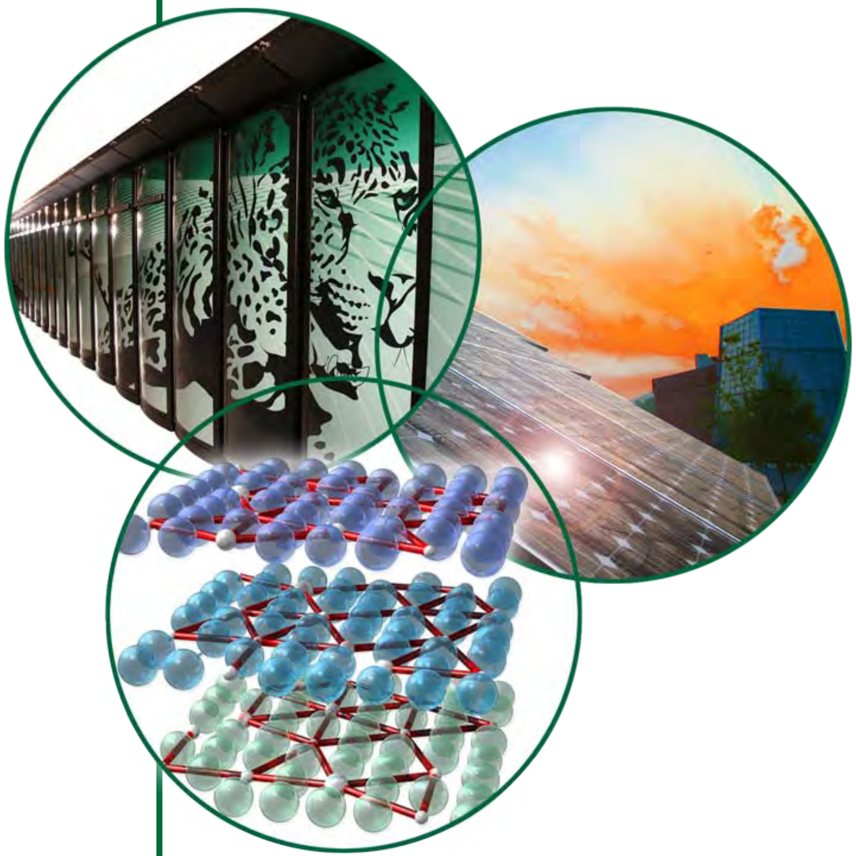


Project ID – PM038

U.S. DEPARTMENT OF ENERGY

Honeywell

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

Overview

Timeline

- Project began – September, 2009
- Project ends – September, 2012
- Project is <50% complete, and extension will be negotiated with Honeywell next year due to expanded commercialization opportunities

Budget

- Total Project Funding
  - DOE Share – 50%
  - Honeywell – 50%
- FY10 DOE Funding - $300,000
- FY11 DOE Funding - $300,000

Barriers

- Changing internal combustion engine regimes
- Long lead time for materials commercialization
- Durability – Current commercially viable materials limit engine efficiency by limiting peak cylinder pressure and exhaust temperatures
- Cost

Partners

- Honeywell's suppliers for turbocharger components
- Materials producers for components

Objective

This CRADA project is relevant to a key technical gap in Propulsion Materials that supports the following Advanced Combustion Engine goal:

2015 Commercial Engine – Improve Thermal Efficiency by 20% over current baseline efficiency

Technical Objective – Higher temperatures (>750ºC, diesel, >950ºC gasoline) exceed the strength and temperature capability of current materials, particularly cast-iron for turbocharger housings

Impact – Turbocharger housing and other components with more temperature capability and strength will enable higher, sustained operating temperatures. Stainless steel turbo-housings will also reduce weight and retain exhaust heat relative to cast-irons

Approach

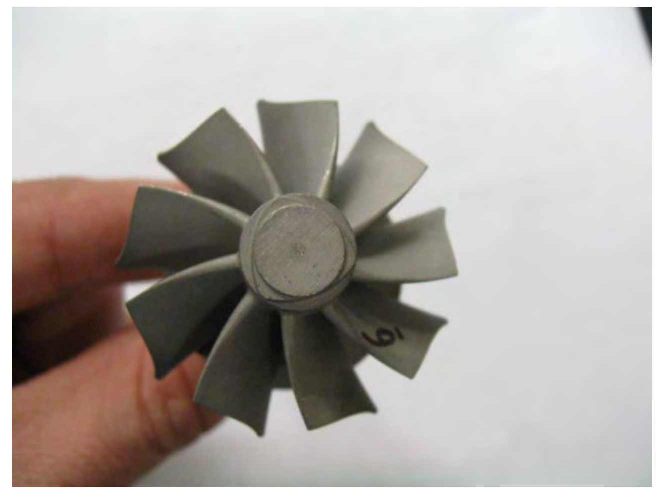
- Honeywell and ORNL have considered current materials used for hot (turbine) and cold (compressor) portions of current turbocharger systems
- Honeywell and ORNL have identified turbocharger housings and turbine-wheel/shaft assemblies as priority components for consideration with increased exhaust temperatures
- Cast austenitic stainless steels have more temperature capability as turbocharger housings than cast-irons
- Weld-joints between steel shafts and Ni-based alloy turbine wheels are the focus of residual stress studies

Milestones

- FY2010 – new project
- FY2011 – begin neutron-scattering residual-stress measurements on wheel/shaft assemblies (Dec, 2010, done)
- FY2011 – complete long-term creep-rupture of cast CF8C-Plus stainless steels (Feb, 2011, done)
- FY2011 – Obtain new turbocharger housings of cast CF8C-Plus stainless steel (August, 2011, on-track)

Technical Accomplishment – HFIR Neutron Scattering on wheel/shaft assemblies

Honeywell supplied wheel/shaft components from gasoline turbocharger products



HTML User-Center at ORNL will use neutron-scattering to measure residual stresses in the weld-joint between Ni-based superalloy wheel and steel shaft

html
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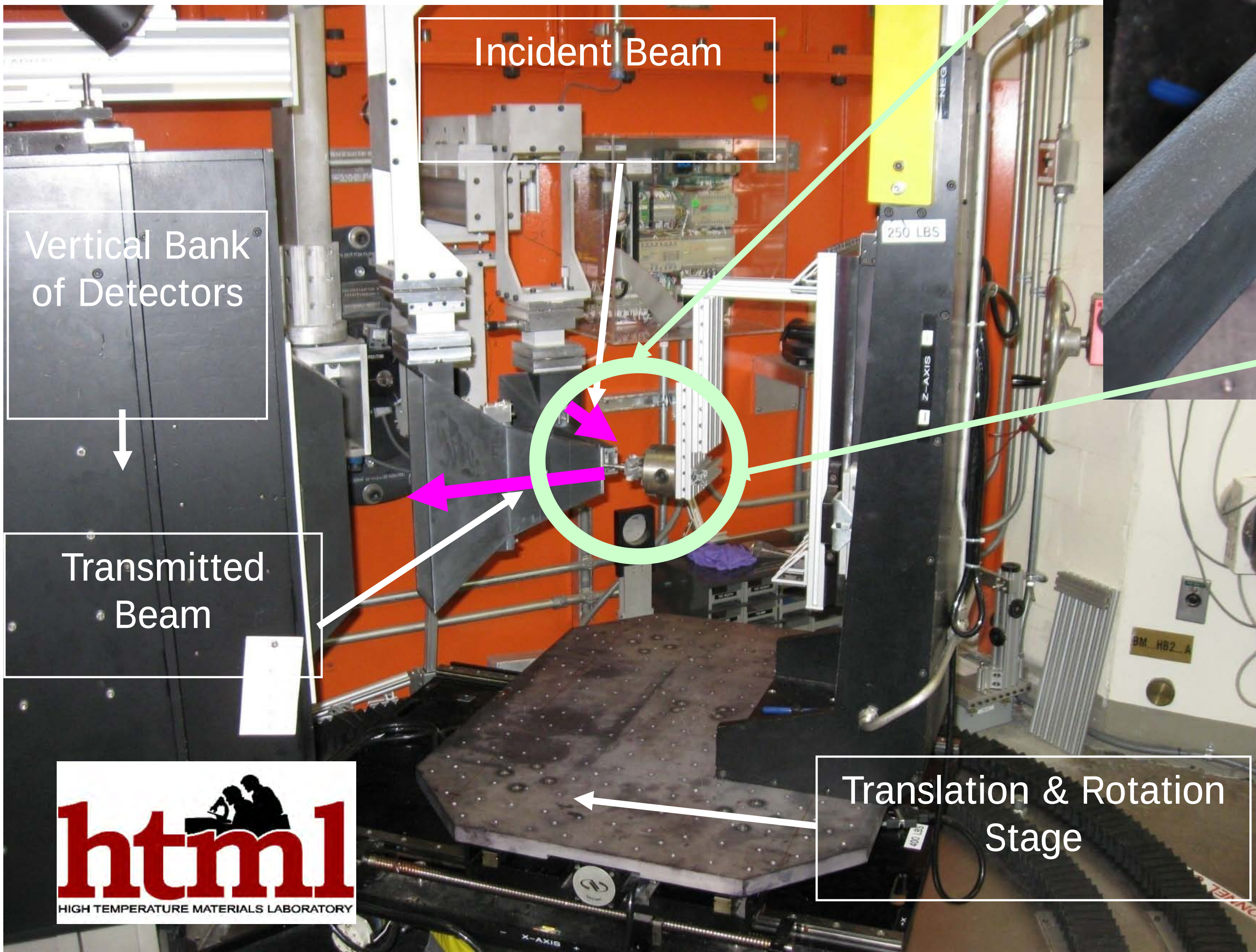
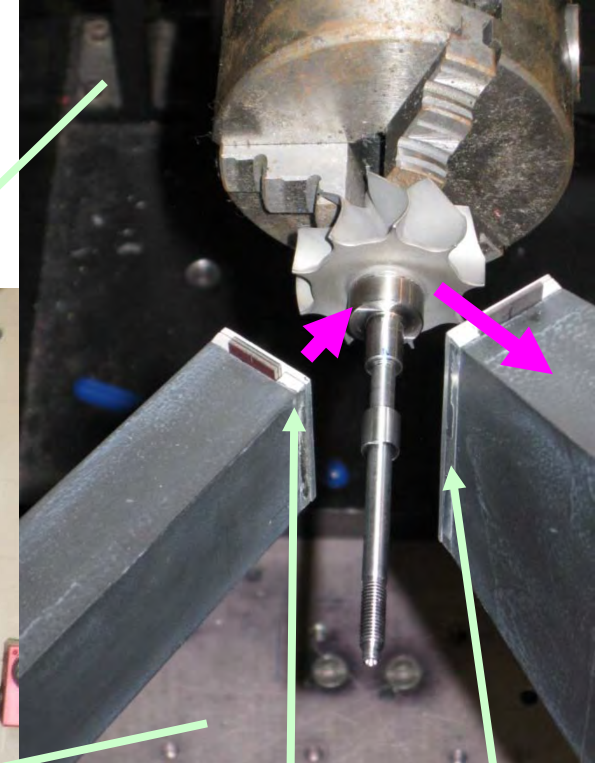
Technical Accomplishments – Initial neutron-scattering experiments done at NRSF2





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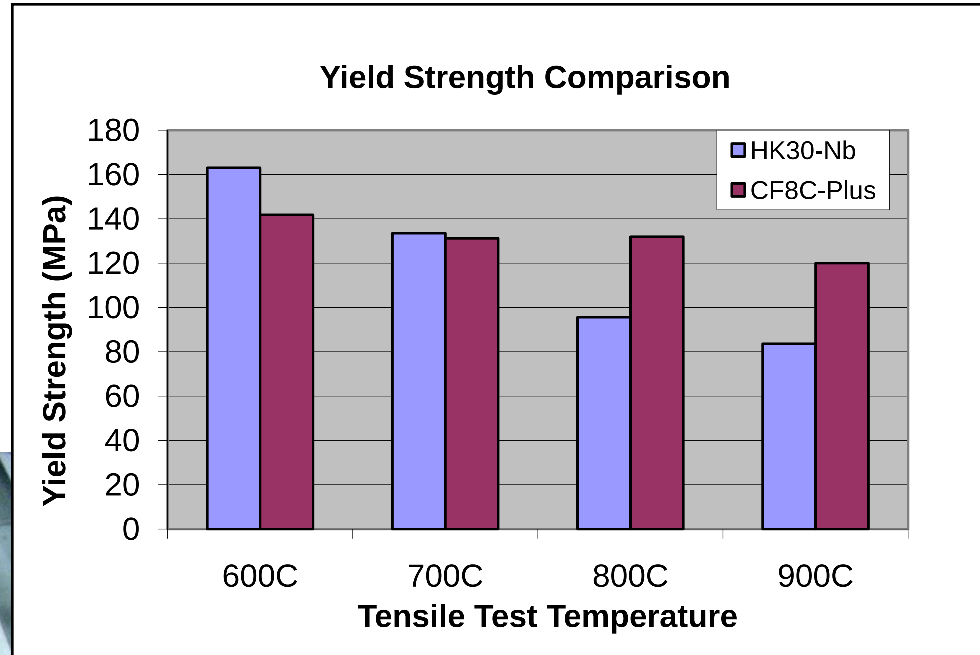
Technical Accomplishments – Upgrade Turbo-Housing to Cast Stainless Steel

ORNL developed CF8C-Plus cast stainless steel with more strength than HK30Nb stainless alloy > 750°C.

Both have much more strength than SiMo cast-iron above 500-600°C



Current SiMo cast-iron turbocharger housing for diesel engine product

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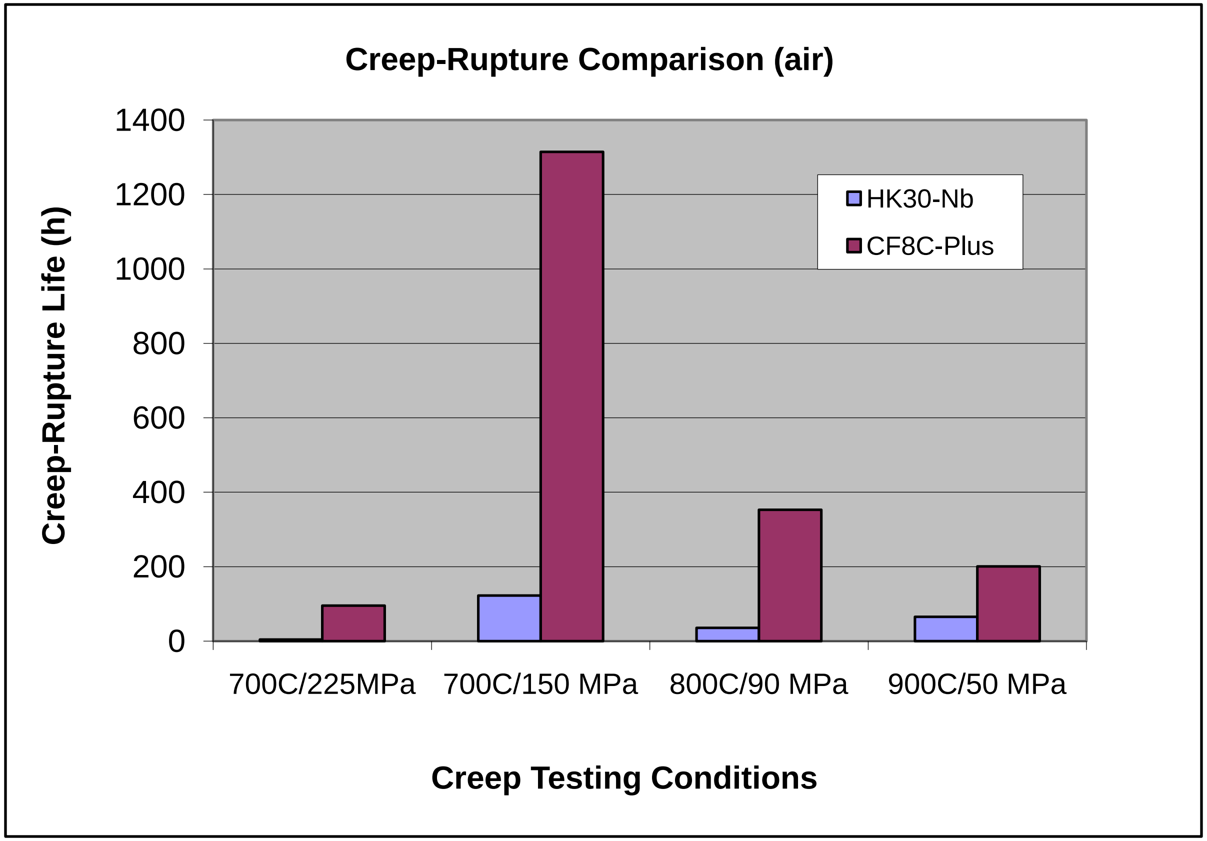
Technical Accomplishments – Upgrade Turbo-Housing to Cast Stainless Steel for More High-Temperature Creep Resistance

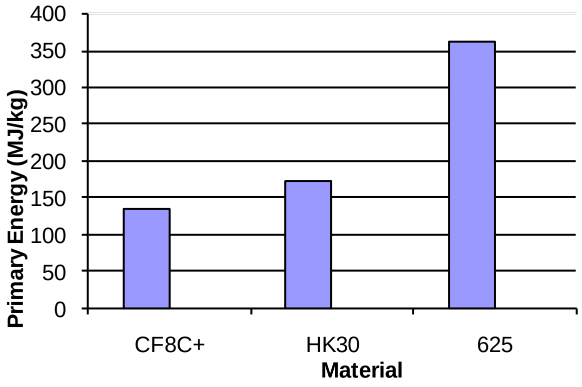


Creep-Rupture Testing of Cast CF8C-Plus stainless steel and HK30-Nb stainless alloy at ORNL

- CF8C-Plus cast stainless steel has significantly better creep-resistance than HK30-Nb stainless alloy at 700-900^{o}C

- CF8C-Plus stainless steel cost is about 33% less than HK30-Nb alloy

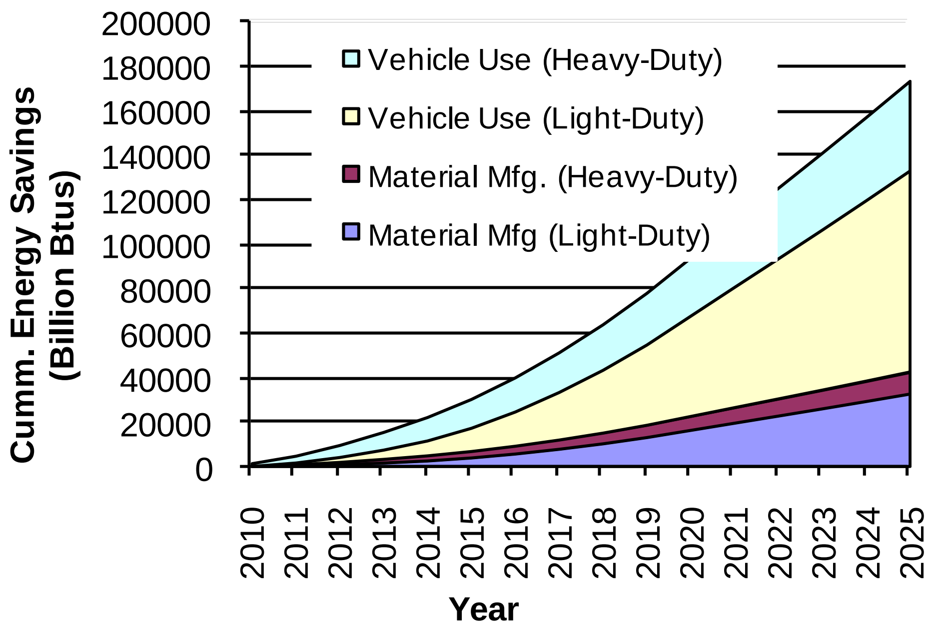
Technical Accomplishments – Upgrading Turbo-Housing to Cast Stainless Steel Saves Energy in Manufacturing and Lifecycle Use



Primary Energy for Making Material, Component and for Lifecycle Use of CF8C-Plus steel, HK30 alloy and Ni-based 625 superalloy

Calculations by S. Das, NTRC, ORNL

- Energy savings in manufacturing and in fuel-efficiency during vehicle lifecycle are compared for CF8C-Plus steel and HK30 alloy
- Using CF8C-Plus steel for turbo-chargers has significant lifecycle energy savings



Collaboration and Coordination with Other Partners

- Honeywell coordinates with its materials suppliers to provide standard and new prototype turbocharger components
- ORNL provides substantial collaboration between this project and Residual-Stress User Center at the High Temperature Materials Laboratory (HTML) for neutron-scattering experiments at HFIR (C. Hubbard and T. Watkins)
- ORNL provides collaboration between this project and the NTRC for economic and energy modeling calculations and analysis (S. Das)

Future Work – Produce stainless steel turbo-housings, test materials for other components and continue residual stress experiments

- Honeywell will work with stainless steel foundry to produce turbocharger housings of CF8C-Plus steel
- Expand properties testing for turbine housing and wheel alloys to include oxidation and fatigue
- Examine effects of processing variables on residual stresses in weld-joints of wheel/shaft assemblies
- Examine residual stresses in critical locations of turbo-charger housings made of SiMo cast iron and CF8C-Plus cast stainless steel

Summary

- Honeywell and ORNL have initially assessed the effects of higher exhaust temperatures on turbocharger materials and components, and prioritized several for more in-depth study
- Residual stresses in weld-joints between Ni-based alloy turbine wheels and steel shafts are a concern that is being addressed with neutron scattering experiments wheel/shaft components at the HTML at ORNL
- Long-term creep-rupture data has shown that CF8C-Plus cast stainless steel has more performance than HK30-Nb stainless alloy as an upgrade for turbo-housings at 700-900ºC
- Economic and energy savings studies show that CF8C-Plus steel is 33% less costly, and produces component manufacturing and vehicle use lifecycle energy savings relative to HK30-Nb stainless alloy for turbocharger housing applications