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Advanced Materials Technology

Austenitic Stainless Steel Alloys for Exhaust Manifolds and Turbochargers

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Project ID
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Austenitic Stainless Steel Alloys for Exhaust Manifolds and Turbochargers

21CTP

21CTP Technical Goal: Develop and demonstrate an emissions compliant engine system for Class 7-8 highway trucks that improves the engine system efficiency from ~42% today to 50% by 2010.

Project Objectives

This 2nd ORNL/CAT CRADA (3y) has been focused on commercialization of the new CF8C-Plus cast austenitic stainless steel to replace SiMo cast iron for advanced diesel exhaust manifolds and turbochargers

FY 2005 Focus

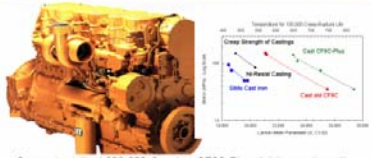
Caterpillar is focused on upgrading turbochargers from cast iron to cast stainless. Direct comparison of CF8C-Plus (MetalTek) and KN2 (Daido) stainless steels is in progress at ORNL to support turbo supplier needs.

Planned Duration

October 2001 to September 2007

DOE Funding/Industry Cost Share

FY04: $160K/$160K; FY05: $160K/$160K



Creep strength at 600-850°C makes CF8C-Plus stainless a dramatic upgrade from SiMo cast iron for thin-walled exhaust manifolds and turbocharger casings

Principal Investigator

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Accomplishments

Creep strength, fatigue and aging resistance prove CF8C-Plus stainless is far superior to SiMo cast iron >600°C; CF8C-Plus and kN2 stainless are being directly compared for turbocharger casing application. CF8C-Plus would give improved durability at increased temperatures and allow up to a 3% decrease in fuel consumption of on-highway trucks.

MetalTek International cast a 6,700 lb gas-turbine end-cover of CF8C-Plus steel, and now has melted >10,000 lb for various commercial applications.

Significant Future Milestones

Complete creep testing of new CF8C-Plus Cu/W for more strength >800°C, (Feb., 2006)

Project ID/Agreement ID	Program Structure	Sub-Program Element	R&D Phase	Date
PM_9112	Materials Technology	HV Propulsion Materials	Applied Research	7-05

Objectives – PM_9112

- The main objective of 2nd ORNL/CAT CRADA (3y + 2y extension in 2005) is to commercialize **CF8C-Plus** cast stainless steel to replace SiMo cast iron for diesel turbocharger housings and exhaust manifolds.
- The FY2005 focus was to complete scale-up properties studies to enable prototyping of upgraded cast stainless turbocharger housings.
- **CF8C-Plus** cast stainless exhaust components help enable the improved engine efficiency goals for Class 7-8 highway trucks.

Approach

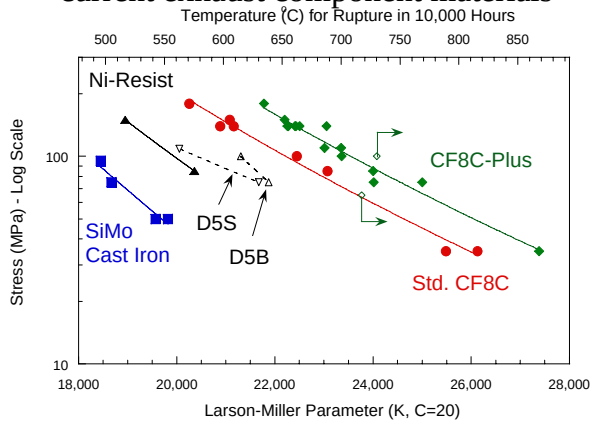
- Caterpillar Inc. provides properties goals and testing requirements for target engine components
- Caterpillar Inc./ORNL provided trial CF8C-Plus license to MetalTek International to cast commercial heats for test components or specimens
- Caterpillar Inc. and ORNL do appropriate mechanical properties testing and micro-characterization to generate data

Relevance to 21CTP Goals

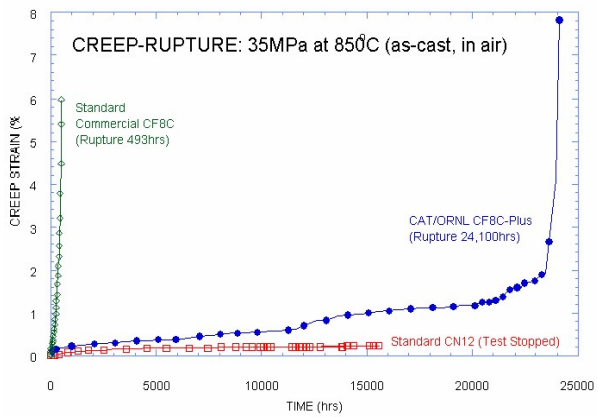
- 21CTP Technical Goal:
  Develop and Demonstrate an emissions compliant engine system for Class 7-8 highway trucks that improves the engine system efficiency from ~42% today to 50% by 2010.
- Method:
  CF8C-Plus allows for a 90°C increase in exhaust gas temperature which translates to roughly a 3% improvement in fuel economy with better durability (compared to SiMo iron).
- Role of 21CTP partners:
  Caterpillar Inc. and ORNL share 50% of the cost each under CRADA agreement.
- Other potential technology benefits:
  - High-end, high-performance automotive turbochargers
  - Centrifugally-cast tubing/piping for petroleum recovery from geological deposits.

Technical Accomplishments:

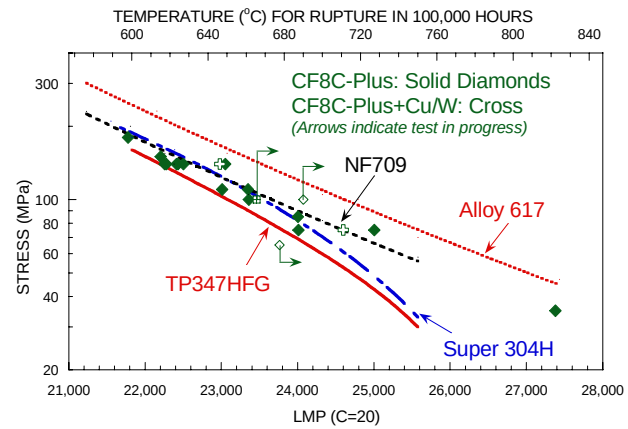
CF8C-Plus cast steel has far more creep strength than current exhaust component materials



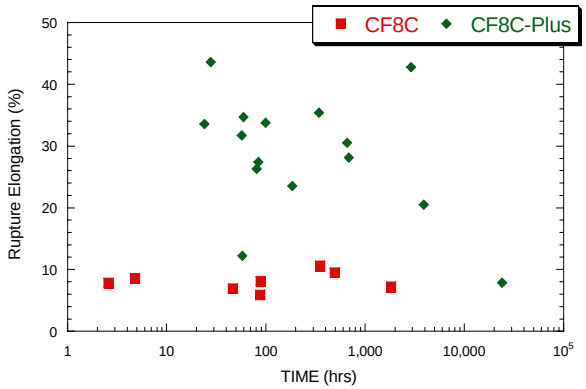
CF8C-Plus creep behavior is more like higher carbon alloys.



CF8C-Plus has better creep strength than many other stainless steels and alloys, and approaches Ni,Co-based superalloy 617

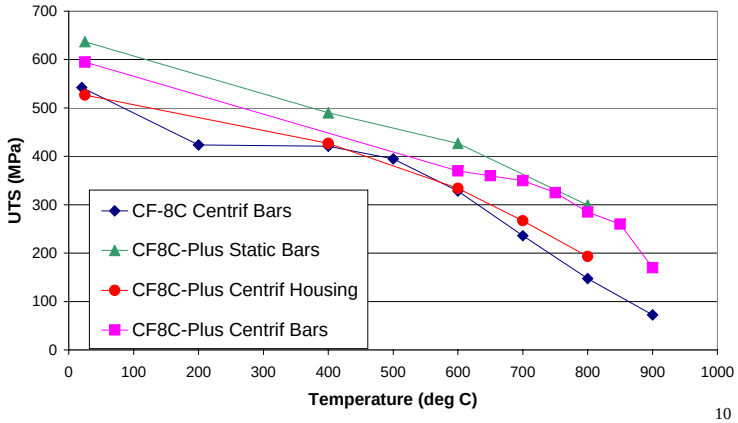


CF8C-Plus steel has better creep ductility in addition to being stronger than standard CF8C

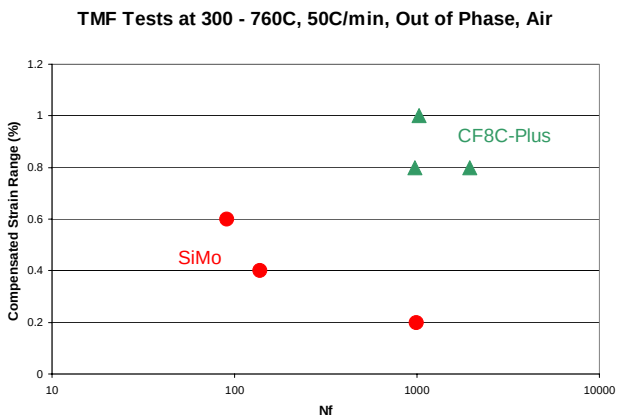


Creep-Rupture Ductility for CF8C and CF8C-Plus tested at 650 to 850C and 35 to 180 MPa

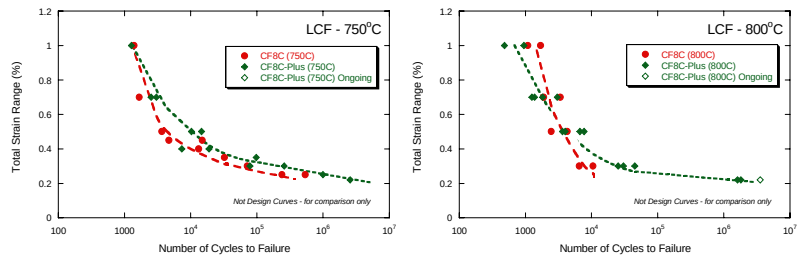
CF8C-Plus has improved tensile properties compared to standard CF-8C.



CF8C-Plus has much more Thermal Mechanical Fatigue (TMF) Resistance than SiMo Cast iron



CF8C-Plus has better fatigue resistance than CF8C at 750-800°C



CF8C-Plus approaches a higher LCF endurance limit than CF8C

Technical Accomplishments

- Improved creep, tensile, LCF, **and** TMF properties over other diesel exhaust component materials.
  - Higher creep resistance usually results in lower ductility and LCF resistance.
- Comparable creep properties to other more expensive alloys for gas turbines.

Technology Transfer

- Good high temperature strength, castability, and cost are driving other applications of **CF8C-Plus** inside and outside of Caterpillar.
- **CF8C-Plus** trial licensees: MetalTek International, Wollaston Alloys, and Stainless Foundry & Engineering.
- Over 30,000 lbs. of **CF8C-Plus steel** were melted through 2005.
- Other large applications for 2005/2006 include large housings for land-based gas turbines, and centrifugally cast tubing/piping for geological oil extraction.

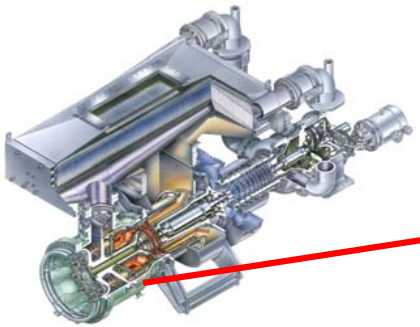
Exhaust Components
CF8C-Plus

- Potential for use of **CF8C-Plus** in turbocharger housings and exhaust manifolds across the board as emissions requirements lead to increased exhaust temperatures.

CAT - Underground Mining Truck

- High ambient temp; many thermal cycles.
- Low field population.
- Perfect test case for stainless upgrade.

CF8C-Plus steel is being tested for Solar Turbines Mercury 50 gas turbine applications



Solar Turbines 4.6 MW Mercury 50 recuperated low NO_x gas turbine engine

6,700 lb **CF8C-Plus** end-cover cast by MetalTek in 2004, and being examined and tested by Caterpillar/ORNL in 2005

Stainless Foundry & Engineering Made **CF8C-Plus Steel** Exhaust Components in 2005

80 lb static sand-cast CF8C-Plus exhaust component

In 2004/2005, MetalTek centrifugally cast over **21,000 lbs** of **CF8C-Plus** tubes for a global petrochemical company technology application.

Future Work

- Extensive LCF, TMF testing for Life Prediction Software.
- Continued characterization of long-term and test-component creep properties of CF8C-Plus and further modifications.
- Commercialization efforts ongoing.

PM_9112 Maziasz - Publications, Presentations, Patents

Patents:

US Patent Application 20030056860 "Heat and Corrosion Resistant Cast CF8C Type Stainless Steel With Improved High Temperature Strength and Ductility," P.J. Maziasz, T. McGreevy, M.J. Pollard, C.W. Siebenaler and R.W. Swindeman, file May 8, 2003.

US Patent Application 20030084967 Heat and Corrosion Resistant Cast CN-12 Type Stainless Steel With Improved High Temperature Strength and Ductility," P.J. Maziasz, T. McGreevy, M.J. Pollard, C.W. Siebenaler and R.W. Swindeman, file May 8, 2003.

Publications:

"Defining the Materials Issues and Research Needs for Ultra-Supercritical Steam Turbines," P.J. Maziasz, I.G. Wright, J.P. Shingledecker, T.B. Gibbons, and R.R. Romanosky, Proc. 4th Internat. Conf. on Advances in Materials Technology for Fossil Power Plants, ASM-International, Materials Park, OH (2005) pp. 602-622.

"Creep Behavior of a New Cast Austenitic Alloy," J.P. Shingledecker, P.J. Maziasz, N.D. Evans, and M.J. Pollard, to be published in Proc. ECCC Conference on Creep and Fracture in High Temperature Components – Design and Life Assessment Issues (12-14 September, 2005, London, UK).

"Alloy Additions for Improved Creep-Rupture Properties of a Cast Austenitic Alloy," J.P. Shingledecker, P.J. Maziasz, N.D. Evans, and M.J. Pollard, Proc. Conf. Creep Deformation and Fracture, Design, and Life Extension, TMS, Warrendale, PA (2005) pp. 129-138.

Presentations:

"Update on ORNL/CAT CRADA on CF8C-Plus Cast Stainless Steel: Progress on Commercial Scale-Up in 2004/2005" P.J. Maziasz, J.P. Shingledecker, N.D. Evans and M.J. Pollard, DOE FreedomCar and Vehicle Technologies Review at ORNL (Sid Diamond) March 2, 2005.

"Development of Low Cost Cast Austenitic Stainless Steel for Diesel Engine and Gas Turbine Applications," M.J. Pollard, P.J. Maziasz and J.P. Shingledecker, DOE Project Review at Caterpillar (Peoria, IL) April 27, 2005.

"Development, Properties, and Applications of CF8C-Plus," P.J. Maziasz, J.P. Shingledecker, N.D. Evans, and M.J. Pollard, Visit to Stainless Foundry and Engineering, Inc., Milwaukee, WI, June 16, 2005.

"Development, Properties, and Applications of CF8C-Plus," P.J. Maziasz, J.P. Shingledecker, N.D. Evans, and M.J. Pollard, Visit to MetalTek International, Inc., Waukesha, WI, June 27, 2005.

"Creep Behavior of a New Cast Austenitic Alloy," J.P. Shingledecker, P.J. Maziasz, N.D. Evans, and M.J. Pollard, Plenary Session Talk at the European Creep Collaborative Committee (ECCC) Conference on Creep and Fracture in High Temperature Components – Design and Life Assessment Issues held 12-14 September, 2005, in London, UK.