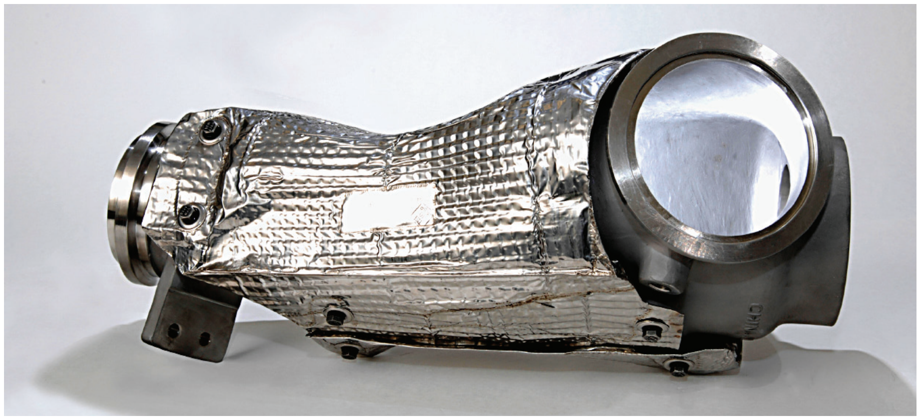
New Steel Advances Engine Exhaust System Design

A new steel endures the higher temperatures of highly efficient, clean diesel engines.

Advanced diesel engines have better fuel efficiency and lower emissions than their predecessors yet must be durable and reliable. As a result, diesel exhaust components such as manifolds and turbocharger housings must endure extreme temperature fluctuations that exceed 750ºC. To meet the performance demands of these advanced diesel engines, Caterpillar Inc. and the U.S. Department of Energy's (DOE's) Oak Ridge National Laboratory (ORNL) partnered to develop a cost-effective material alternative to the silicon-molybdenum cast iron which is typically used in cast diesel exhaust components. Commercial cast stainless steels such as CF8C have some desired properties but lack others. Sponsored from 2002 to 2008 by DOE's Vehicle Technologies Program, the two partners developed and tested a modified version of the standard cast stainless steel, CF8C-Plus. The new material has outstanding high-temperature properties, is more castable, and still costs about the same as standard CF8C steel.

In 2003 Caterpillar produced the first commercial heats of the new stainless steel. ORNL and Caterpillar received an R&D 100 Award in 2003 from *R&D* magazine for their codeveloped CF8C-Plus technology, which was judged one of the most significant innovations of that year. Since then, ORNL and Caterpillar have established trial licenses for CF8C-Plus with other companies, including General Electric and Stainless Foundry & Engineering, which obtained the first commercial license in May 2008. Honeywell signed a cooperative research and development agreement with ORNL for testing CF8C-Plus for both diesel and automotive engine turbocharger applications. In 2009 the CF8C-Plus technology brought ORNL an award for excellence in technology transfer from the Federal Laboratory Consortium. CF8C-Plus is currently in the advanced stages of testing and qualification by several large U.S. companies for new applications beyond exhaust components.



Burner housing made of CF8C-Plus steel and designed for the pyrolytic breakdown of carbon particulates trapped in ceramic particulate filters downstream of the burner in a Caterpillar Regeneration System

Technology

CF8C-Plus is a low-cost cast stainless steel that offers high performance at the high temperatures demanded of diesel engines, gas turbines, and nuclear reactors. The engineering of the microstructure of CF8C, which cannot withstand temperatures above 600–650ºC, dramatically transforms

Benefits

- *High-temperature strength in the 650–900ºC range*
- *Great resistance to fatigue and age-induced failure*
- *Low-cost weldable austenitic grade of steel*
- *Excellent castability for ease of air-casting large or small components*
- *No heat treatments required after casting*
- *Creep strength comparable to nickel-based superalloys*
- *Approved by ASTM as a heat-resistant alloy, HG10MNN*

the steel to an alloy that can endure temperatures of 850ºC and above and resist mechanical fatigue, thermal fatigue, and age-induced creep failure.

The standard CF8C steel is a niobium-stabilized, iron-19 chromium-10 nickel (Fe-19Cr-10Ni) cast stainless steel that contains 20–25% delta-ferrite, which has some benefits at lower temperatures. However during aging or at temperatures above 600–650ºC, delta-ferrite in CF8C induces rapidly deteriorating corrosion resistance and weakens the steel.

Additions of manganese and nitrogen, along with careful adjustments to the CF8C alloy composition, eliminate the undesirable delta-ferrite and stabilize the austenite matrix phase. As a result, no deleterious intermetallic phases precipitate during prolonged thermal aging. The new alloying additions enhance the formation and stability of nanoscale dispersions of niobium carbides and nitrides, which then provide creep strength to CF8C-Plus at temperatures as high as 900ºC.

The CF8C-Plus cast stainless steel is stronger yet has about the same high ductility as standard steel. The combination of strength and ductility over a wide temperature range gives the new steel resistance to fatigue, thermal fatigue, and age-induced creep failure. The addition of manganese gives the CF8C-Plus more castability than standard steel, an ideal property for casting thin- or thick-wall components for diesel engine exhaust.

Solar Turbines' 4.6 megawatt Mercury 50 gas turbine engine end cover

Commercialization

Commercial scale-up of CF8C-Plus began in 2003 with the production of 500-pound, air-melted, static cast heats by several commercial stainless steel foundries. By the end of 2004, more than 10,000 pounds of CF8C-Plus steel had been cast, and trials had begun on components ranging from large castings for industrial gas turbines to smaller castings appropriate for making diesel engine exhaust components. From fall 2006 to August 2009, more than 450 tons of CF8C-Plus steel had been cast for Caterpillar's Regeneration System units, the first commercial application. Today U.S. industry is leading the world in the development and testing of this revolutionary, low-cost, high-performance steel that is poised to reduce the weight and cost of turbochargers and other key components for many of the world's next-generation, high-efficiency diesel engines.

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Energy Efficiency and Renewable Energy

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

More Information
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