U.S. Department of Energy • Office of Energy Efficiency and Renewable Energy

Oak Ridge National Laboratory

Heavy Vehicle Propulsion Materials

Hot New Steel Promising for High-Temperature Applications

Background

Researchers at ORNL and Caterpillar have developed a new stainless steel that is stronger and tougher at both high and low temperatures than standard steels without costing more. Not only the steel itself but also the method of producing it, termed “engineered microstructures” are being hailed as revolutionary.

The new technology received a 2003 R&D 100 award from *R&D Magazine*, recognizing it as one of the most significant scientific achievements of the year. The magazine noted that CF8C-Plus “improves upon the common grade of CF8C (Fe-20Cr-10Ni-Nb-C) steel in both strength and ductility (usually a trade-off) in the temperature range between 20°C and 850°C” (*R&D Magazine*, September 2003).

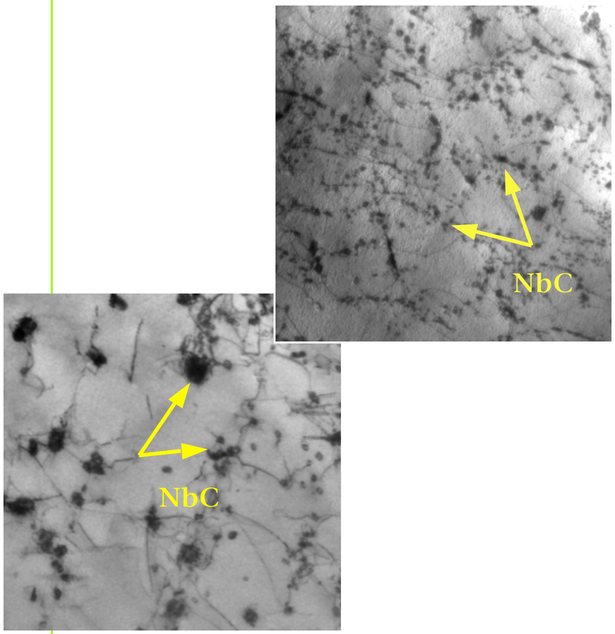
Development of the new steel, CF8C-Plus, was driven by the need for engine components that can perform reliably at temperatures of up to 800–850°C. Higher engine operating temperatures result in greater fuel efficiency and lower emissions. The new material can be used in both vehicle engines and in large, stationary engines used for power generation. The project was co-sponsored by the Department of Energy’s Distributed Energy and Electric Reliability Program.

The Technology

CF8C-Plus was made by making changes to the composition of CF8C, a common stainless steel. Careful additions of manganese and nitrogen, adjustment of the other alloy components, and microscale and nanoscale manipulation of the grain structure produced the improvements.

Ordinarily, there is a tradeoff between strength and ductility (flexibility); the stronger the steel, the more brittle and prone it is to cracking. CF8C-Plus contains scattered particles of niobium carbide (NbC), which adds strength at high temperatures. However, the alloy is engineered so that the NbC nanoparticles form only after the material is exposed to high temperatures during service. It is less strong, and thus more ductile, during the casting phase, but gains the strength it needs after it is put into use. Consequently, it is easier to cast than most competing steels and needs

Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle



CF8C-Plus (at top right) has superior creep resistance at 850°C because of its abundant, stable, nanoscale niobium carbide (NbC) pin dislocations as compared to commercially available, standard CF8C (bottom left).

no post-casting heat treatment or processing.

Whereas CF8C cast steel is reliable at temperatures up to 650°C, CF8C-Plus is strong, ductile, and resistant to fatigue and creep behavior up to 850°C. Few steel alloys are usable at temperatures higher than 850°C, and those are more difficult to cast and more susceptible to fatigue and creep at high temperatures. CFC8-Plus also has shown outstanding resistance to oxidation.

Commercialization

Immediate applications planned for CF8C-Plus are exhaust components, such as manifolds and turbocharger housings, for heavy-duty diesel engines. It is expected to be directly applicable for many other uses, including marine diesel engines, industrial gas turbines, microturbines, gasoline automotive engines, natural gas reciprocating engines, and large, advanced land-based gas or steam turbines.

Benefits

- Vehicle engines can operate reliably at higher temperatures for increased fuel efficiency and decreased emissions
- Easy to cast
- No post-casting heat treatment or processing needed
- No additional cost over conventional stainless steels

Where Can I Find More Information?

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Department of Energy Secretary Spencer Abraham and Senator Lamar Alexander examine a CF8C-Plus casting held by Phil Masiasz, ORNL principal investigator.

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