PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Advanced Research

08/2007

Steam Turbine Materials for Ultra Supercritical Coal Power Plants

Description

Research and development (R&D) is needed on advanced materials for steam turbines to enable them to be used with highly efficient ultra-supercritical (USC) steam cycles that operate at much higher temperatures and pressures than those presently used in conventional pulverized coal (PC) power plants. In addition to higher efficiency, USC steam cycles offer the advantage of reducing carbon dioxide emissions through more complete fuel combustion, helping to further the mission of the U.S. Department of Energy (DOE) to make today's coal-fired power plants cleaner, and to enable tomorrow's systems to perform with near-zero emissions.

A major five-year national effort to develop materials for USC boilers is under way, sponsored by DOE and the Ohio Coal Development Office (OCDO). This effort is being carried out by a consortium of the Energy Industries of Ohio (EIO), Electric Power Research Institute, Inc. (EPRI), Oak Ridge National Laboratory, and four domestic boiler manufacturers. Clearly, a corresponding level of effort is needed to develop materials technology for USC steam turbines to match the USC boiler conditions, and is a priority leading to a full-scale demonstration and eventual commercialization of USC power plants.

The project described here is a significant first step toward achieving these goals. It is a three-year effort led by DOE's National Energy Technology Laboratory (NETL) and EIO, with team members also including Alstom, GE Energy, Siemens Westinghouse, Oak Ridge National Laboratory, and EPRI. As part of this development effort, new high-temperature, alloys will be selected and evaluated with respect to their resistance to creep, fatigue, and oxidation under the harsh steam conditions of 1400 °F and 5,000 pounds per square inch. Erosion and corrosion resistant coatings also will be investigated.

Objective

The overall objective of this project is to contribute to the development of materials technology for use in power plant steam turbines capable of operating in PC-fired plants under the harsh operating conditions described above. The project is designed to provide materials that are necessary to withstand the higher steam temperatures and pressures required for USC operation. These materials will have the ability to be shaped into a finished product and will demonstrate resistance to creep, oxidation, corrosion, and fatigue. The coatings to be developed will resist oxidation and erosion.

Technical Approach

The overall approach is first to identify high-potential candidate alloys for critical components for both welded and mono-block rotor configurations The project

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PROJECT DURATION

09/29/05 to 09/30/08

COST

Total Project Value
$2,702,729

DOE/Non-DOE Share
$2,031,006 / $671,723

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then branches into two parallel efforts for evaluating the mechanical and corrosion properties of the candidate materials and coatings for use in : (1) rotors, buckets, and bolting materials; and (2) valves and cylinder body casing materials. The effort on rotors is further divided into welded and mono-block, or solid rotors. Tasks to be performed include the following:

Task 1: Identify coatings that will protect high-temperature turbine components from excessive steam oxidation and from solid particle erosion (SPE) at inlet temperature up to 1,400 °F.

Task 2: Identify suitable "super alloy" candidate materials and processes for welding to conventional rotor materials, to minimize the use of expensive super alloy rotor components.

Task 3: Identify suitable materials that can be made into a single-piece rotor or the highest temperature portion of a mechanically coupled rotor, buckets, and bolting operating in a steam turbine with an inlet temperature of 1,400 °F.

Task 4: Identify suitable materials that can be used in large sand castings for valve and cylinder bodies, and which are also repairable; and to develop material properties for design.

Task 5: Assess the cost and performance tradeoffs associated with the use of 1,400 °F steam turbine materials and their weld joint properties; and integrate the understanding developed during the project to ensure that a coherent vision is developed for USC steam turbines.

Accomplishments

Accomplishments to date essentially consist of extensive surveys of literature and industry experience, designed to identify candidate materials and coatings for the critical components that have already been identified and procured. Test plans have been developed and test equipment located; and many of the mechanical tests are in progress. A preliminary conceptual design for welded rotor construction has been developed and welding trials have been initiated.

Benefits

This project is expected to contribute to the development of materials technology for use in power plant steam turbines capable of operating in PC-fired plants under high-temperature and high-pressure USC operating conditions. Successful development will lead to a full-scale demonstration and eventual commercialization of highly efficient, low-emissions USC PC power plants. Deployment of this technology will result in a nearly 30 percent improvement in efficiency and a corresponding reduction of all effluents and waste products including CO_2 .

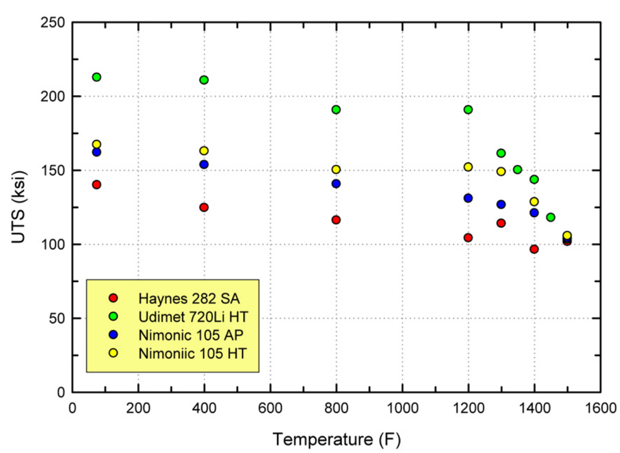

Figure. 1
UTS as a function of temperature for Haynes 282 SA, Udimet 720Li HT, Nimonic 105 AP, and Nimonic 105 HT