the ENERGY lab

PROJECT FACTS

Hydrogen Turbines

Ultra-High Temperature Thermal Barrier Coatings—HiFunda & University of Connecticut

Background

The U.S. Department of Energy (DOE) has a stated goal to increase the energy efficiency of turbines, and one well recognized method of achieving this goal is through the use of ceramic thermal barrier coatings (TBCs). However, state-of-the-art zirconia-based TBCs have a temperature limit of about 1200 degrees Celsius (ºC). New TBC materials that can withstand temperatures of 1300 °C and above are needed to increase turbine operating temperatures and achieve associated gains in energy efficiency.

HiFunda LLC and the University of Connecticut (UConn) are teaming to demonstrate an advanced TBC consisting of a new top coat chemistry of yttrium aluminum garnet (YAG) with a unique microstructure, which has higher use temperature, greater erosion resistance, improved sintering resistance, and lower effective thermal conductivity compared to the widely used yttria-partially stabilized zirconia (YSZ) top coats.

This turbine project was competitively selected under the Small Business Technology Transfer (STTR) Program. It is managed by the U.S. DOE National Energy Technology Laboratory (NETL). NETL is researching advanced turbine technology with the goal of producing reliable, affordable, and environmentally friendly electric power in response to the nation's increasing energy challenges. With the Hydrogen Turbine Program, NETL is leading the research, development, and demonstration of these technologies to achieve power production from high-hydrogen-content fuels derived from coal that is clean, efficient, and cost-effective, minimizes carbon dioxide (CO_2) emissions, and will help to maintain the nation's leadership in the export of gas turbine equipment.

Project Description

Prior to this project, the use of YAG materials as TBCs has been limited by the difficulty of processing them with a sufficiently compliant microstructure to achieve the required strain tolerance and durability. This project will use a proprietary solution precursor plasma spray (SPPS) process—developed at UConn and demonstrated successfully on other materials such as YSZ—to fabricate YAG-based TBCs with markedly improved temperature characteristics relative to YSZ. In Phase I, the team demonstrated the feasibility of utilizing the SPPS process to deposit TBC coatings of sufficient thickness and desirable microstructures that yielded superior thermal cycling resistance compared with state-of-the-art air plasma sprayed (APS) YSZ coatings. In Phase II, HiFunda and UConn—working closely with major turbine manufacturers and coating service providers—will optimize the process, demonstrate that SPPS YAG TBCs can meet test criteria specified by the turbine manufacturers, and scale up the process to coat components for third party testing.

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PROJECT DURATION

Start Date	End Date
02/20/2012	04/21/2015

COST

Total Project Value
$1,149,988

DOE/Non-DOE Share
$1,149,988 / $0

AWARD NUMBER

DE-SC0007544

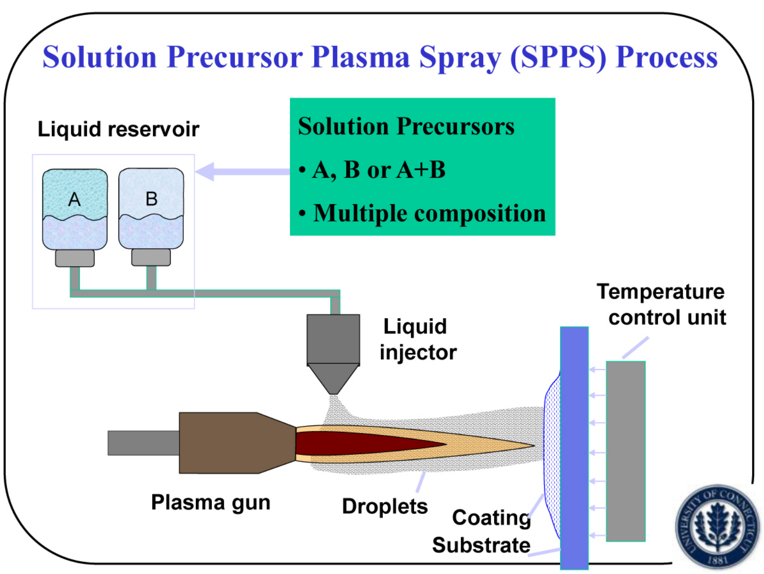
U.S. DEPARTMENT OF ENERGY

Goals and Objectives

The Phase I goal was met by demonstrating, using laboratory tests, that SPPS YAG TBCs have properties that can be tailored to provide superior durability, use temperature, and sintering/ erosion resistance, and lower thermal conductivity than YSZ TBCs.

The specific technical objectives for Phase II are as follows:

- Establish the HiFunda Incubator Plasma Spray Facility at UConn with staff and equipment.
- Select an optimum precursor that can provide the desirable SPPS YAG TBC microstructure without nozzle clogging.
- Identity optimum SPPS plasma spray processing parameters, using Taguchi Design of Experiments, based on SPPS microstructure (thickness >250 µm, vertical cracks, ultra-fine splats), and with lower thermal conductivity, lower density, and increased hardness (>300 VHN [Vickers Hardness Number]) compared to APS YSZ.
- Demonstrate that SPPS YAG TBCs have a >200 °C temperature capability compared to APS YSZ, along with greater sinter and erosion resistance, superior durability, equivalent or improved CMAS (Calcium-Magnesium-Alumina-Silicate) resistance and lower thermal conductivity.
- Demonstrate a production-capable process for SPPS YAG TBCs.
- Provide cost estimates for SPPS YAG TBCs relative to baseline APS YSZ TBCs.



Accomplishments

- Identified SPPS processing parameters that could achieve the desirable microstructural features of high porosity and vertical cracking.
- Successfully sprayed coatings of greater than 250 µm thickness that have the desired microstructure.
- Showed that SPPS YAG TBCs have lifetimes that matched or exceeded baseline YSZ TBCs at both standard- and elevated- temperature thermal cycling conditions.
- Established a HiFunda technology incubator at UConn.

Benefits

This STTR project supports DOE's Hydrogen Turbine Program, which is striving to show that gas turbines can operate on coal-based hydrogen fuels, increase combined cycle efficiency by three to five percentage points over baseline, and reduce emissions. The STTR program is positioned to leverage the agility and innovative competencies of small businesses. The novel TBCs developed by the HiFunda team can be an enabling technology for highly efficient next-generation gas turbines.