the ENERGY lab

PROJECT FACTS

Advanced Turbines

Advanced Laser Machining Techniques for Cooling Holes in Gas Turbines—Physical Sciences

Background

Physical Sciences Inc. (PSI) has developed a high speed, water guided laser drilling process that will improve the predictability and repeatability of cooling hole performance in gas turbine blades while meeting manufacturing cost objectives. The water guided laser drilling process will also enable cost-effective machining of shaped cooling holes that are desired for next generation turbine cooling strategies. Funding by the American Recovery and Reinvestment Act (ARRA) under the Small Business Innovation Research (SBIR) Phase II Program will further develop the water guided laser drilling process by demonstrating superior flow uniformity compared to holes drilled using current laser or electrochemical methods. A prototype drilling system will be constructed to demonstrate that the technology will meet productivity and cost objectives of turbine manufacturers.

This project is managed by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL). NETL is researching next generation turbine technology with the goal of producing reliable, affordable, and environmentally friendly energy supplies in response to the nation's increasing energy challenges. With the Advanced Turbine Program, NETL is leading the research, development, and demonstration of these technologies to achieve power production from coal that is clean, efficient, and cost-effective, minimizes carbon dioxide (CO_2) emissions, and will help maintain the nation's leadership in the export of gas turbine equipment.

Project Description

PSI will develop a high speed, water guided laser drilling process for creating cooling holes in high temperature metallic alloys used in gas turbine systems. Current drilling technologies produce cooling holes with plus or minus 10 percent (± 10%) air flow variation between identically drilled arrays of holes. This variation requires designers to provide extra holes and extra cooling flow to ensure safe operation, but it results in an excess consumption of cooling air and over cooling in some areas. The novel PSI approach will reduce flow variation to ± 2%, permit more complex cooling hole shapes, and allow for more precise location of cooling holes on turbine blades. In addition, water guided laser drilling will improve the predictability and repeatability of cooling performance and meet manufacturing cost objectives to enable next generation turbine cooling strategies.

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PERFORMANCE PERIOD

Start Date
12/07/2009

End Date
08/31/2012

COST

Total Project Value

$1,148,653

DOE/Non-DOE Share

$1,148,653 / $0

Government funding for this project is provided in whole or in part through the American Recovery and Reinvestment Act.

AWARD NUMBER

SC0003400

Goals/Objectives

The program goal is to demonstrate a module that can be attached to a commercial laser drilling head and deliver laser energy to the surface of a work piece through a high pressure stream of water. Objectives of the Phase II program are as follows:

(1) design and build a water guided laser drilling head that can be used to drill holes up to 0.050" in diameter anywhere on the surface of a 12" x 12" panel of high temperature alloy—with the head capable of drilling holes at elevation angles from 90° to 20° through a water stream extending up to 25 mm from the head;

(2) integrate a water guided laser drilling head into a prototype water guided laser drilling system so that all positioning and drilling operations may be performed from a single computer numerical control (CNC) operator interface;

(3) develop water guided laser drilling processes that enable arrays of holes to be automatically drilled with user defined diameters and elevation angles anywhere on the surface of a 12" x 12" substrate at rates exceeding 3 seconds/hole;

(4) demonstrate that the air flow variation of between arrays of holes drilled using water guided laser drilling is less than ±2%;

(5) perform metallurgical analysis of the surfaces of water guided laser drilled holes and show that the microstructure of the walls of the holes contain no microcracks, and that debris generated by the drilling process is not deposited on the walls of the holes or forms a ridge on either the entry or exit; and

(6) define the requirements for a production water guided laser drilling system capable of drilling cooling holes for gas turbine systems.

Accomplishments

- Demonstrated water guided laser drilling of 0.18" diameter through holes in 0.050" Inconel 718 alloys at rates exceeding the 3 seconds/hole required for the cost effective production of gas turbine components.
- Adapted the water guided laser drilling head to a YLR-1000-SM fiber laser cutting system.

Benefits

The SBIR program is positioned to leverage the agility and innovative competencies of small businesses. It is through this program that a small company, Physical Sciences in Andover, Massachusetts, has developed an advanced technology for drilling precise holes that is critical for building higher efficiency, greener gas turbines and other systems. ARRA investment in this small business will likely result in more U.S. jobs, as well as both the processes and equipment necessary to transition this vital technology to manufacturers of gas turbine systems.

PSI's Phase I water guided laser drilling system (a). The system was used successfully to (b) drill through holes in 0.050" Inconel 718 at rates exceeding 3 seconds/hole with small amounts of surface recast on the laser entry and exit.