the ENERGY lab

PROJECT FACTS

Hydrogen Turbines

Advanced Cooling for IGCC Turbine Blades—Mikro Systems

Background

Turbine blade and vane survivability at higher operating temperatures is the key to improving turbine engine performance for integrated gasification combined cycle (IGCC) power plants. Innovative cooling approaches are a critical enabling technology to meet this need.

Mikro Systems, Inc. is applying their patented Tomo-Lithographic Molding (TOMO) manufacturing technology to produce turbine blades with significantly improved internal cooling geometries that go beyond the current manufacturing state-of-the-art to enable higher operating temperatures. This project addresses two important aspects. First is the need to increase the quality and reliability of the core manufacturing process capability to enable advanced cooling features to be incorporated into future turbines. Second is the need to rapidly and economically produce tools and prototype hardware whereby advanced designs can be empirically tested and optimized.

This project is managed by the U.S. Department of Energy (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 maintain the nation's leadership in the export of gas turbine equipment. This project was competitively selected under the Small Business Innovative Research (SBIR) Program.

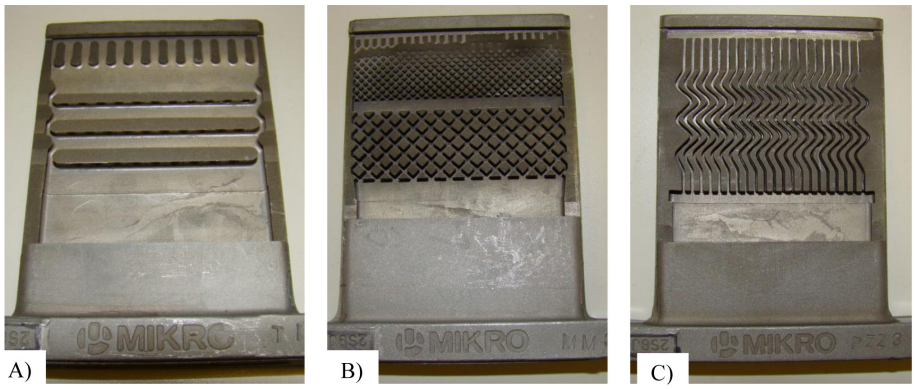

Figure 1. Filleted DS metal castings of the three cooling channel design variants created using Mikro's TOMO technology: (A) triple impingement, (B) multi-mesh, and (C) zig-zag.

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PARTNERS

Purdue University
Siemens Energy

PROJECT DURATION

Start Date	End Date
08/12/2009	08/14/2012

COST

Total Project Value
$1,099,896

DOE/Non-DOE Share
$1,099,896/$0

AWARD NUMBER

SC0001359

U.S. DEPARTMENT OF ENERGY

Project Description

In order to improve heat transfer and lower cooling air requirements, the advanced blade designs will require more complex internal cooling passages than can be produced using current investment casting techniques. Significant gains can be made, especially on the trailing edge (TE) portion of the turbine blade. Under this project Mikro has produced advanced cooling geometries in TE coupons that could be used on the TE of blades used in IGCC power plants.

Purdue University has applied computational fluid dynamics (CFD) analysis to model the heat transfer of the proposed trailing edge designs produced by Mikro Systems. Siemens Energy has developed a test rig to empirically measure heat transfer performance using Mikro's TE coupons.

Goals and Objectives

The overarching goal of this Phase II effort is to demonstrate that Mikro System's TOMO technology can produce a multitude of designs that have the potential to provide significant improvements in heat transfer for advanced turbine blades. This enables a synergistic relationship between design, manufacturing, CFD modeling, and experimental testing by allowing for design comparisons in a short time period. Fiscal year (FY) 2011 objectives are as follows:

- Refine the trailing edge cooling design produced in Phase I and optimize the design using outputs and results from the Phase I core production and investment casting trials to configure trailing edge coupons for FY 2011.
- Produce two additional design variants by modifying the trailing edge portion of the blade.
- Conduct heat transfer testing focused on the advanced geometries embedded in Phase II coupons.
- Perform CFD testing and analysis on the advanced blades and verify the optimized cooling performance.

The FY 2012 objective is to produce tooling and "foundry ready" ceramic cores that have advanced TE designs on a full-size blade that can be metal cast and tested for improvements in heat transfer for advanced turbine blades.

Accomplishments

- Mikro produced models of three trailing edge designs with advanced cooling features for production and CFD analysis.
- Mikro produced ceramic core samples of each design, plus seven additional designs with slight variants. Mikro waxed the cores and the foundry metal cast using directional solidification of CM247.
- Purdue University conducted CFD analysis on three trailing edge designs.
- Siemens has begun heat transfer testing on 29 metal cast trailing edge coupons using infrared imaging (10 design variants in all).

Benefits

This SBIR project supports DOE's Hydrogen Turbine Program that 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 SBIR program is positioned to leverage the agility and innovative competencies of small businesses. It is through this program that a small company, Mikro Systems, has developed a way to revolutionize the gas turbine industry's investment casting process. Mikro Systems has created breakthrough technology for both development and manufacturing of ceramic casting cores. It enables faster and lower-cost development of advanced gas turbine blades, and the process can be scaled up for volume production. Further, Mikro Systems technology supports design features that are not possible with conventional core casting technology.

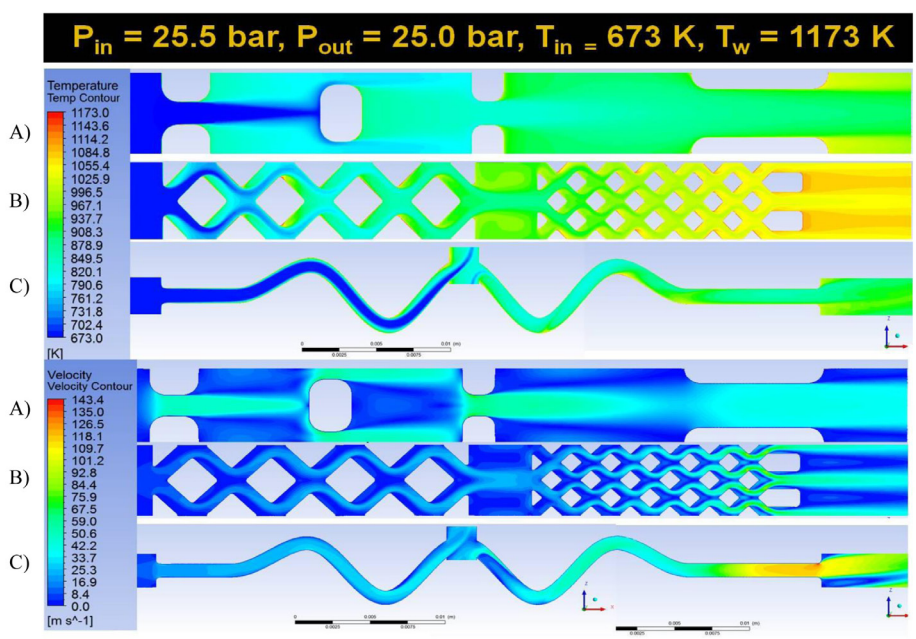

Figure 2. Sample of the analysis completed by Purdue University of three TE design variants: (A) triple impingement, (B) multi-mesh, and (C) zig-zag.

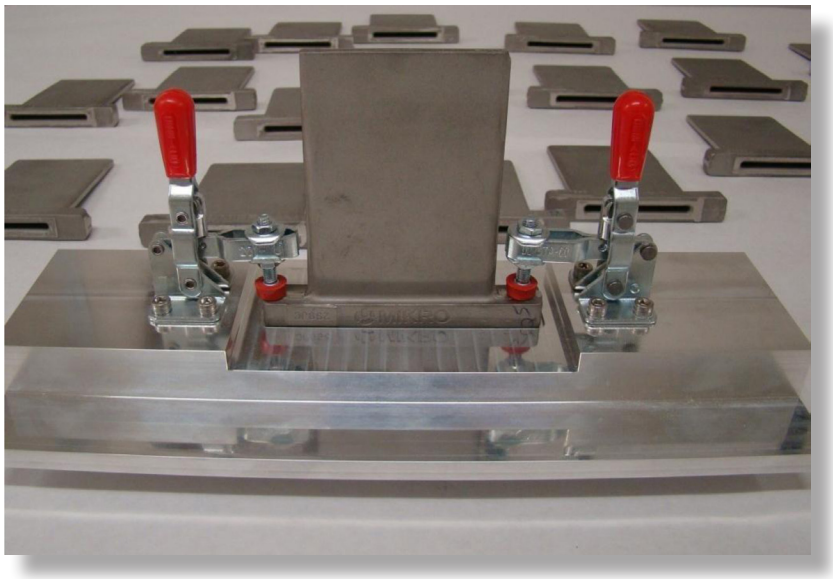

Figure 3. TE coupon in GIS testing fixture in front of castings with design variants.

Figure 4. TE coupons—exit end.