Ultra-High Temperature Thermal Barrier Coating Development and Validation

DE-EE0008307

Solar Turbines Incorporated, Solution Spray Technologies LLC

Project Period 1

Brent Cottom (PI), Solar Turbines Incorporated

U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
June 11-12, 2019

Overview

Project Title: Ultra-High Temperature Thermal Barrier Coating Development and Validation

Timeline:

Project Start Date: 05/01/2018

Budget Period End Date: 08/31/2019

Project End Date: 08/31/2021

Barriers and Challenges:

- Current thermal barrier coatings have debits in maximum temperature limit (1200°C), durability and corrosion resistance
- Process robustness and deposition rate

AMO MYPP Connection:

- Materials for Harsh Service Conditions

Project Budget and Costs:

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$2,399,591	$774,471	$3,174,062	24.4%
Approved Budget (BP1)	$778,016	$251,106	$1,029,122	24.4%
Costs as of 4/30/19	$464,199	$149,820	$614,019	24.4%

Project Team and Roles:

- Solar Turbines Incorporated
  - Program Manager: Jeff Price
  - Principal Investigator: Brent Cottom
- Solution Spray Technologies LLC (SST)
  - Solution Precursor Plasma Spray (SPPS) process development and optimization
  - Dr Jordan, Dr. Gell, Dr. Nair, Dr. Kumar, Dr. Jiang, and J. Roth

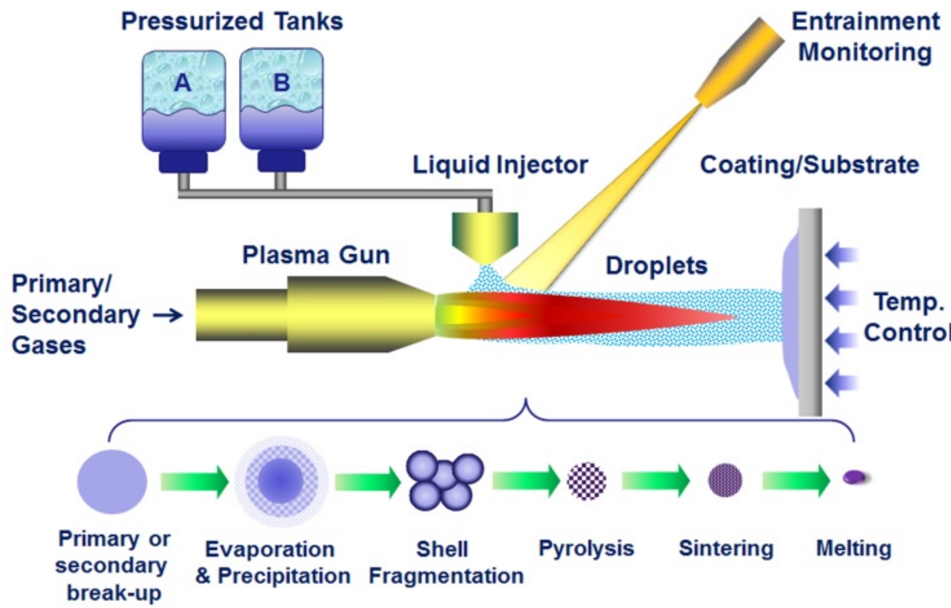
Project Objectives

- Increasing the efficiency of gas turbines is an important goal for DOE and Mfg industry (to reduce GHG & operating costs)
  - Higher operating temperature results in gas turbines with higher efficiency
  - Current thermal barrier coatings have debits in maximum temperature limit (1200°C), durability, and corrosion resistance
- This Project will implement, improve (process and properties), and demonstrate a thermal barrier coating with +200°C temperature increase
  - Manufacturing improvements with a higher enthalpy torch
  - Optimized coating properties with graded porosity
  - Develop Manufacturing process for full-scale components
  - Rig demonstration of higher temperature capability & durability
  - Development engine test on combustion and turbine components

Technical Innovation

- Solution Precursor Plasma Spray (SPPS) will be used to apply yttrium aluminum garnet (YAG) with unique microstructure characteristics

  - Phase stable crystalline YAG
  - Improved erosion and corrosion resistance
  - Higher thermal cycle durability
  - Lower thermal conductivity
  - Higher temperature capability (+1400 °C)

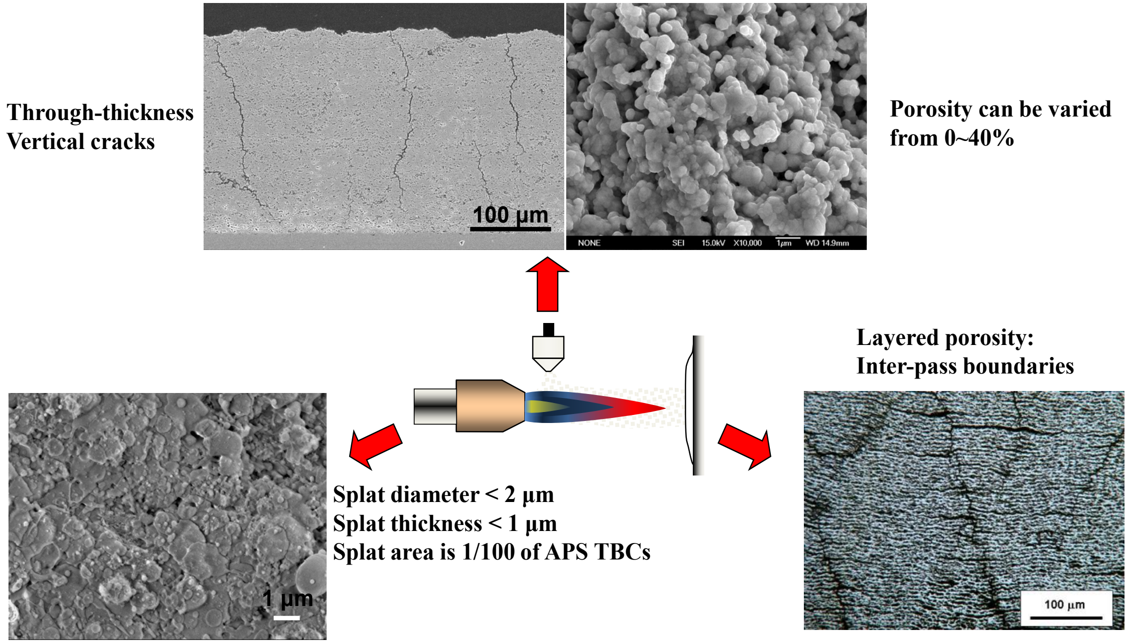


Material Challenges: bulk YAG has lower thermal expansion and higher thermal conductivity

Process Challenges: standoff distance, low deposition rates, part temperature control

Technical Innovation

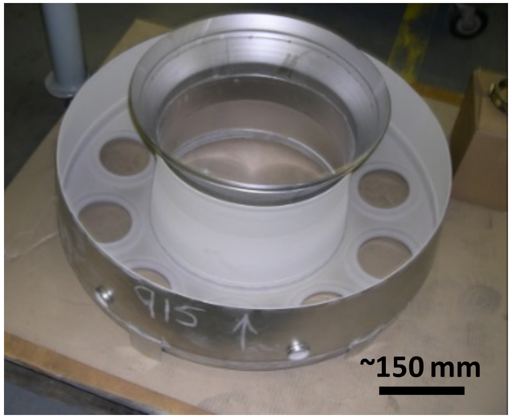
- Generate microstructures with strain tolerant through thickness cracks and porosity - inherent and inter-pass boundaries (IPBs)



- Prior testing has demonstrated durability in both laboratory and rig testing along with better insulating capability

Technical Approach

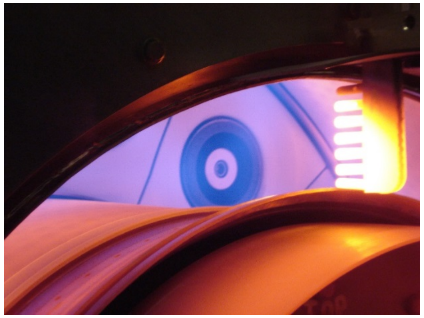
- Implement the Solution Precursor Plasma Spray Technology initiated at the Univ. Connecticut/Solution Spray Technologies (SST)
- Improve application process using the higher enthalpy torch with SST's process experience
- Develop and improve process for application on gas turbine hardware progressing from combustion injector components followed by more complex liners and turbine components

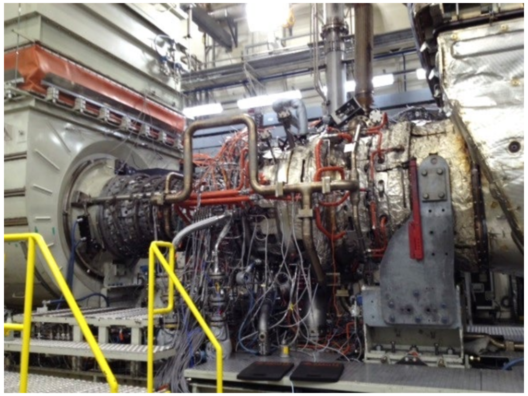


Technical Approach

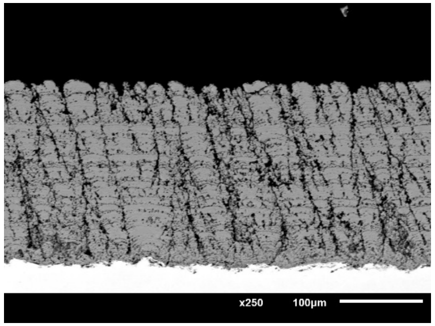
- Develop processing capability to grade coating porosity and tailor coating properties for specific application
  - Control process settings for continuous porosity grading
  - Increase porosity for abradability and to reduce thermal conductivity
  - Decrease porosity to improve resistance to erosion and corrosion
  - Grade coatings for optimal thermal cycling durability

- Demonstrate and validate higher temperature capability and durability in both rig and development engine testing

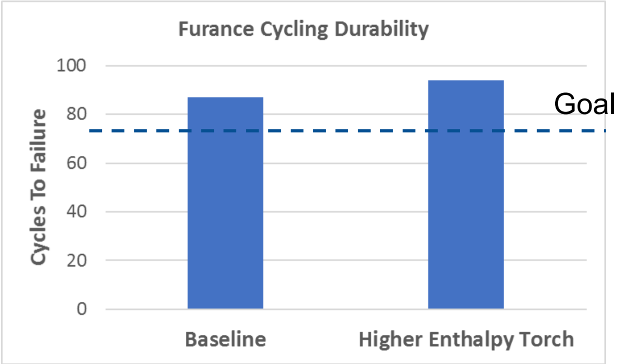




Results and Accomplishments



- Replicated process and fabricated coatings at Solar with acceptable properties to program milestone requirements
- Achieved program goals for higher enthalpy torch parameter evaluation and identified key parameters to fabricate coatings with acceptable properties
- Increased process standoff by 50% and deposition rate by 70%
- Fabricated coatings from low to high density and evaluated for microstructure, hardness, thermal conductivity, furnace cycle durability and erosion resistance



- Demonstrated a coating with a 0.5 W/mK thermal conductivity, even lower than the program goal of 0.6 W/mK at 1300°C
- On track for go/no-go milestone on graded coating evaluation

Transition

- Validate long-term durability of the coating through additional development engine testing and further optimize application process

- Successfully development engine testing will substantiate field trials of the coating technology

- The coating will be evaluated by Solar for other applications
  - Other engine models as upgrades/uprates
  - New engine models as they are developed
  - Other turbine parts (e.g., turbine blades)

- SST will continue to advance the solution precursor coating process and evaluate other potential applications