Presentation to the UTSR Workshop, Ohio State University October 27, 2011

The UTSR Impact: Key Accomplishments, Benefits to OEMs and Status of the Fellowship Program

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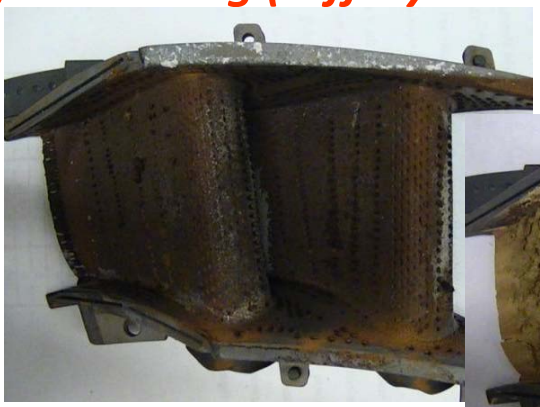
Key Accomplishments

- Since the program started in 1992 over 100 research projects have been completed
- The following slides summarize two examples in each UTSR technology area from recently completed projects
  - Aerodynamics / Heat Transfer
  - Materials
  - Combustion
- The benefits to the gas turbine industry are also shown for each project

Deposition Resistant Turbine Designs

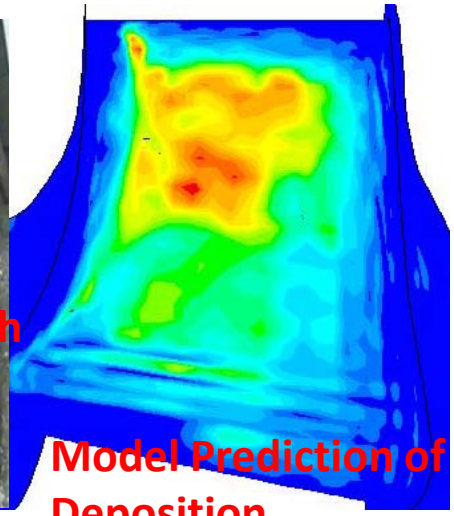
Ohio State and Brigham Young (Jeffrey Bons #5055)

- Improved understanding of deposition may lead to more deposition-tolerant designs and improved turbine performance with various feedstocks.
- OSU's rig simulates a deposit-laden turbine flowfield with real turbine hardware.
- BYU's rig simulates deposit-laden operating environments up to 2500F
- Turbine hardware supplied for evaluation by GE, SPG, and Praxair



Exposure to Bituminous Ash Particulate at 2050F

Exposure to Lignite Ash Particulate at 1950F

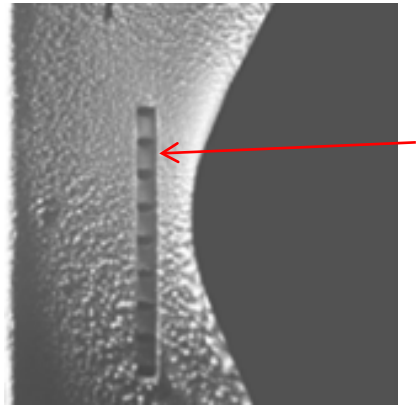


- Results show significant effect of coal ash grade on deposition…at lower temperatures for lower rank coal.
- New deposition model captures deposition buildup
- Computational results provide OEMs with capability to assess deposition-resistance during component design.
- Computational model will allow design of deposition resistant turbines
- Results solicited by GE, P&W, SPG for potential use.

Improved film cooling on vanes and endwalls with coolant holes embedded in shallow trenches

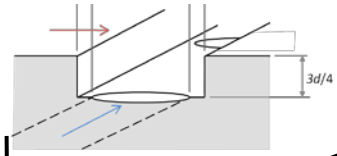
David Bogard Texas and Karen Thole Penn State #SR127

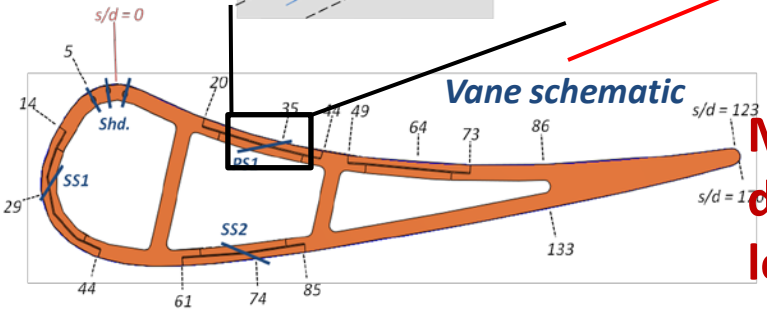
Image of trench on the endwall upstream of a vane leading edge



Coolant holes embedded in a trench are protected from blockage by depositions of contaminants.

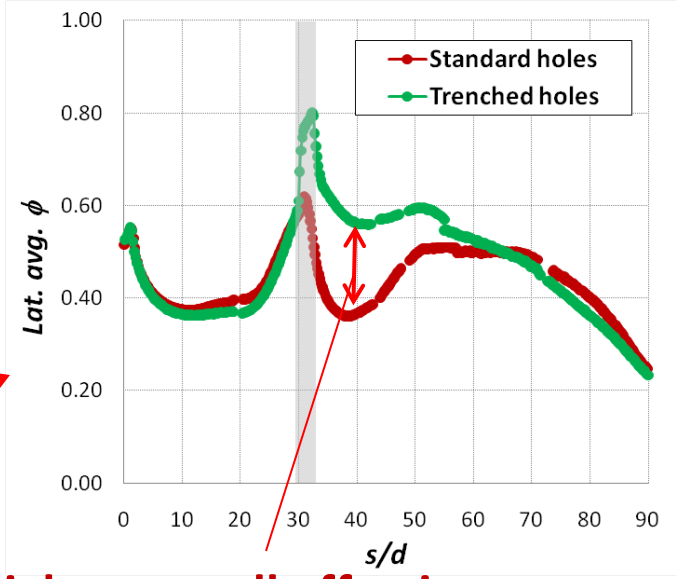
Trench schematic





Vane schematic

Overall effectiveness (ϕ) of film cooling is significantly improved when coolant holes are embedded in a trench.

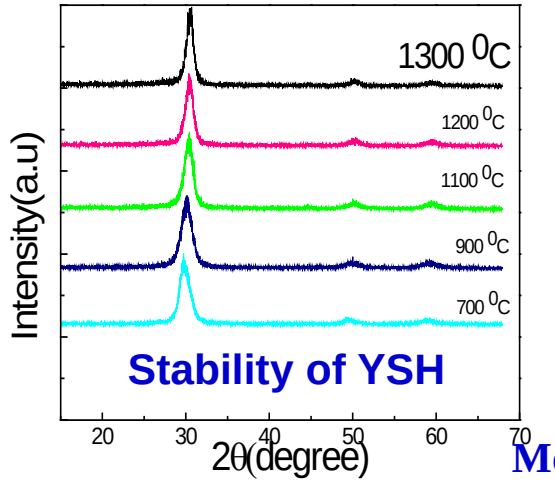


Much higher overall effectiveness downstream of the trench eliminates local hot spot that would lead to turbine vane failure.

***Several industry sponsors have used results from our studies of shallow trench film cooling configurations to develop proprietary configurations for practical applications.**

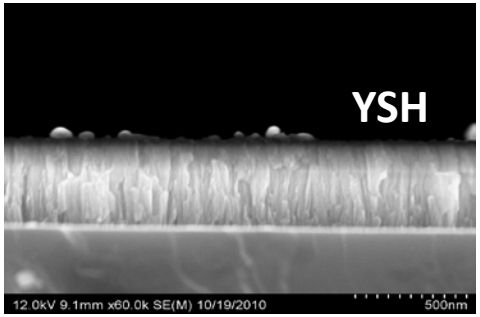
Hafnia-based Nanostructured Thermal Barrier Coatings for Advanced Hydrogen Turbine Technology

U. Texas El Paso Chintalapalle #NT0000765

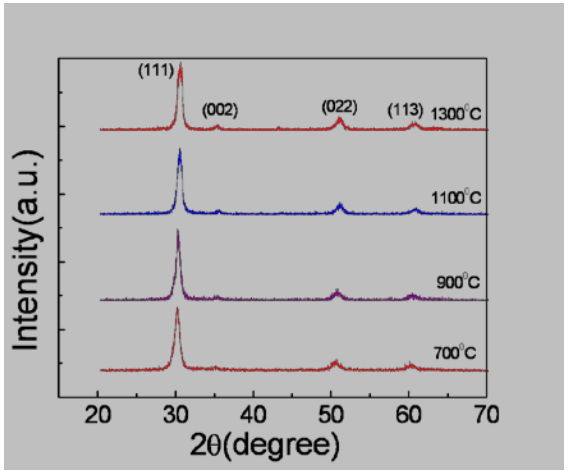


Stability of YSH

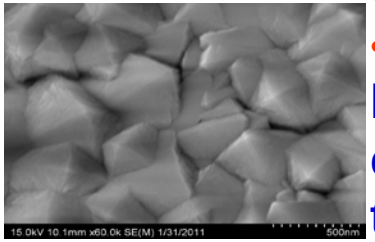
Microstructure of YSH and YSHZ Coatings



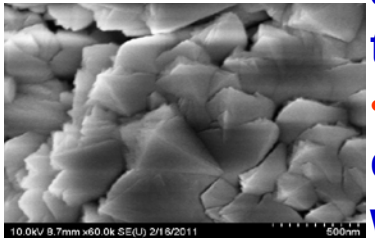
Thermal Stability:YSHZ-1



Morphology



YSH on SS-403



YSH + BC on Ni alloy

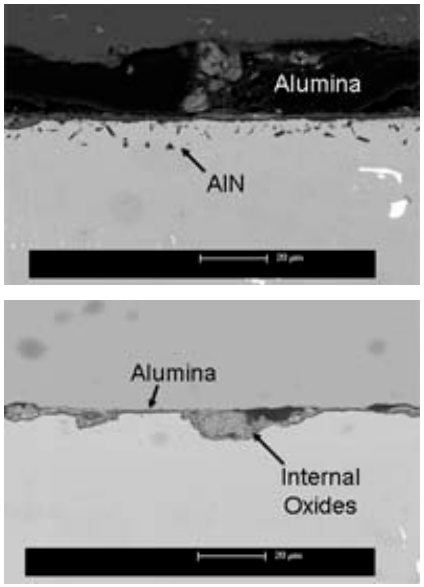
- This project is intended to develop and engineer hafnia-based TBCs.
- Demonstrated that yttria stabilized hafnia (YSH) and yttria stabilized hafnia co-doped with zirconia (YSHZ) exhibits the cubic phase and columnar structure, which is stable to higher temperatures.
- YSH and YSHZ coatings showed enhanced thermal stability to 1300 ^{o}C, which is higher than YSZ
- Two GT manufacturers are using the results demonstrated in the project

Materials for Oxy-Fuel Turbomachine Conditions

U. of Pittsburgh - Jerry Meier

Turbine Need

- Previous materials development for power generating gas turbines performed for natural gas/air combustion.
- Coal-based oxy-fuel systems will result in combustion gases which are hotter and contain high levels of H_2O and CO_2.
- Need to determine the effects of relevant gases on the degradation of gas turbine alloys and coatings.

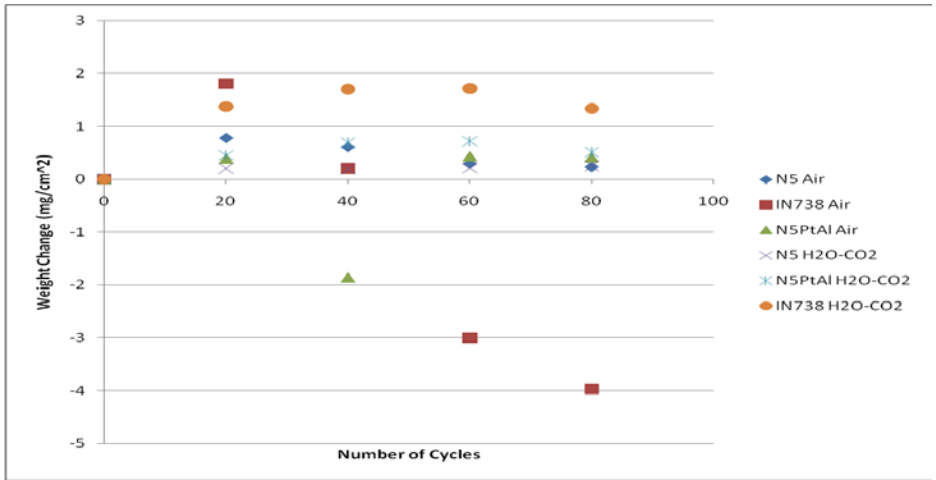


Dry Air

Rene' N5

85%H_2O-15%CO_2

Cyclic Oxidation Kinetics – 1100°C



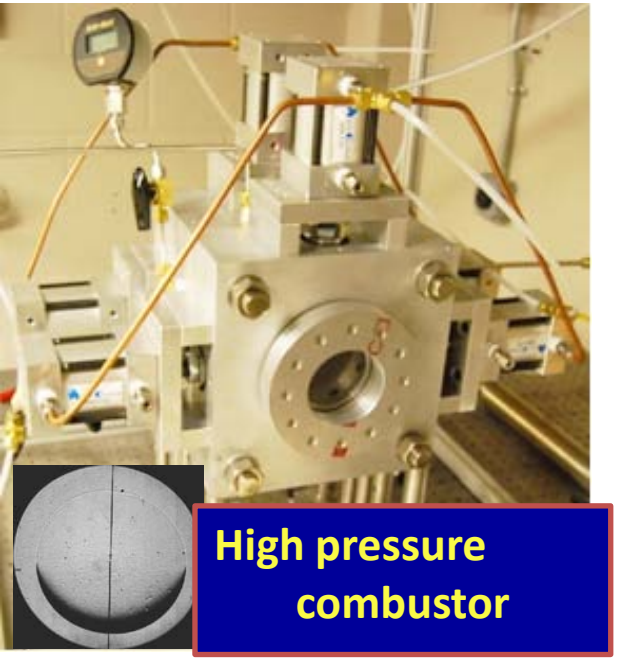
Summary

- Oxyfuel Environments are no more severe than Air for highly-resistant superalloys, metallic coatings and TBCs.
- Oxyfuel Environments disrupt the selective oxidation process for borderline alloys.

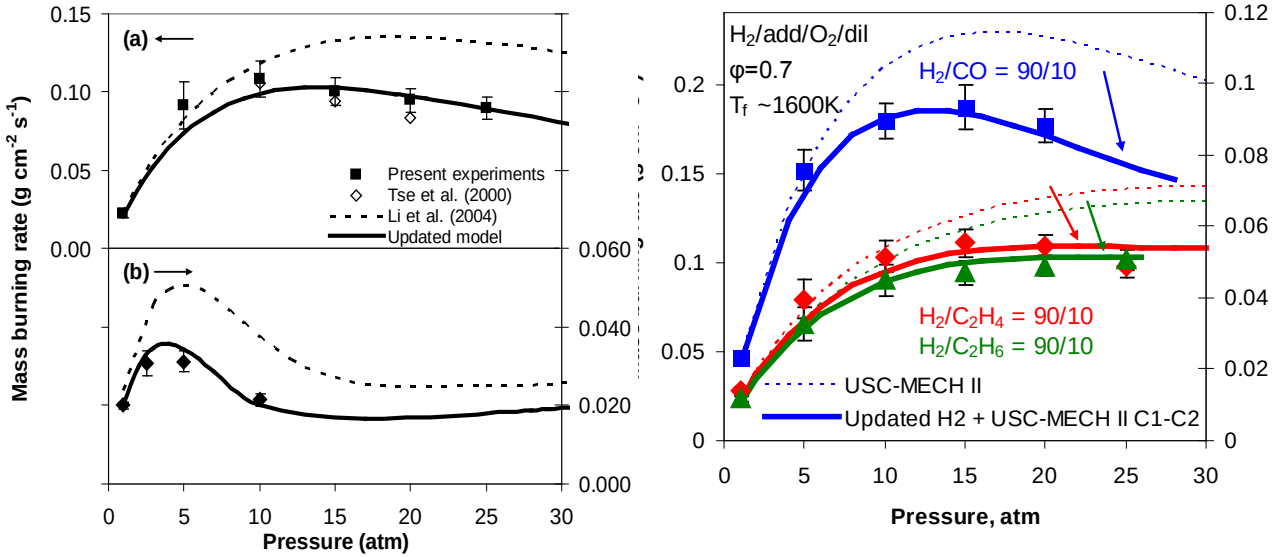
May be an issue for components in the later stages of design life.

Development of a validated chemical kinetic mechanism for high hydrogen syngas turbines

Princeton University, Yiguang Ju / Fred Dryer # NT0000752



Measurements of high pressure flame speeds and improved model prediction for high hydrogen syngas



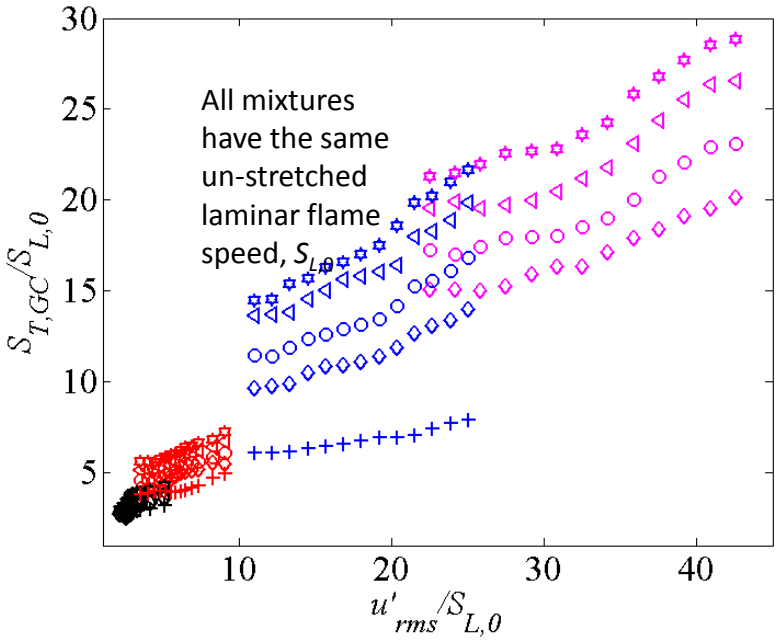
High pressure combustor for flame speed measurements at relevant pressures:

- **Understanding of flame flashback and combustion dynamics require accurate measurements of flame speeds of high hydrogen syngas mixtures at high pressure.**
- **Obtained the high pressure hydrogen flame speeds for both lean and rich mixtures.**
- **Developed a comprehensive hydrogen mechanism to predict accurately pressure dependence of flame speed at high pressure.**

Siemens Inc. and Amyris Inc. have used the experimental data and facilities for the engine development and fuel design, respectively.

Turbulent Flame Speed Measurements and Modeling of Syngas Fuels

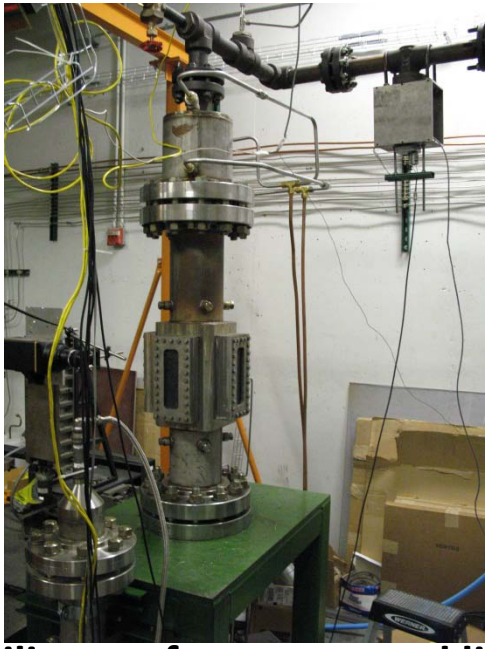
Georgia Tech
J. Seitzman *et al.* -SR122



H_2/CO: 90/10
H_2/CO: 70/30
H_2/CO: 50/50
H_2/CO: 30/70

CH_4/air

High pressure test facility



- **Fuel composition has critical influences on key combustor operability, performance, and life**
  - **e.g., flashback/blow-off propensities, liner and nozzle thermal loadings, combustion instability limits**
  - **Turbulent flame speed, $S_{T,GC}$, has leading order influence on these operational metrics**
- **Obtained $S_{T,GC}$ measurements of various H_2/CO mixtures over a wide range of conditions**
  - **Demonstrated significant impact of fuel composition on $S_{T,GC}$ over gas turbine relevant conditions**
- **Developed model to capture these fuel composition impacts**
  - **model being used by industry partners as design tool for developing high H_2 gas turbines**

Benefits to OEMs

- The following slides summarize the benefits to the OEMs from the UTSR research projects and from the Fellowship Program

Benefits to OEMs: Research Projects (1/3)

- Help shape annual UTSR solicitation research topics – Within the program scope focus solicitation research topics to meet your companies gas turbine technology needs.
- Participate in UTSR proposal evaluations – Substantial involvement in the proposal evaluation process insuring the best proposals are selected to meet program goals.

Benefits to OEMs: Research Projects (2/3)

- Participate in the UTSR Industry Committee Meetings – Meet and collaborate with industry peers to help guide and focus UTSR research and workshops to meet industry goals.
- Participate in UTSR Workshop Planning Meetings – Interact with DOE, universities and industry to suggest better ways to conduct the annual workshop and the UTSR Program.

Benefits to OEMs: Research Projects (3/3)

- Participate in the UTSR Workshop – Help inform university researchers on industry needs and priorities by participating in UTSR Workshop plenary panels.
- Host students in the Gas turbine Industrial Fellowship Program – following slides

Benefits to OEMs: Fellowship Program (1/2)

- Host student(s) fellows proportional to dues level – Work with and assess some of the best students in the nation for future employment as they work on real world problems.
- The students have been encouraged by their professors to apply and are interested in the gas turbine industry; an advantage in recruiting future employees.

Benefits to OEMs: Fellowship Program (2/2)

- <u>Historically, 80% of the UTSR Fellows benefit the gas turbine industry</u>
  - 70% of them accept jobs with companies in the gas turbine industry
  - Another 10% stay in academia, teaching and researching on gas turbine topics

Status of the Fellowship Program

- Starting in the fall of 2010, Southwest Research Institute is implementing the program for NETL, with oversight from LTI, site support contractor for NETL.
- 2011 Fellowship Program data:
  - 32 Applicants
  - 12 Fellows selected
  - 11 Universities
  - 9 Host Companies

Fellowship Host Companies 2011

- GE
- Siemens
- Solar Turbines
- FlexEnergy
- Woodward governor
- Southern Co.
- Parker Hannifin
- EPRI
- Clean Energy Systems
- Florida Turbine Technologies

2011 Fellows (1/3)

Fellow	University	Company
Dam, Bidhan Kumar	University of Texas at El Paso	Siemens
Bernier, Bryan Carl	University of Central Florida	Florida Turbine Technologies
Bolin, Christopher	Michigan State University	Flex Energy
Paul, Christoper J.	Michigan State University	Parker Hannifin

2011 Fellows (2/3)

Fellow	University	Company
Liu, Kevin	Texas A&M University	Siemens
Kolshak, Leonard Max	Florida Atlantic University	GE
Mihelish, Matthew	University of North Dakota	Solar Turbines
Weber, Patrick	University of Wyoming	EPRI

2011 Fellows (3/3)

Fellow	University	Company
Tan, Phillip	Princeton University	Woodward
Murphy, Robert	West Virginia University	Solar Turbines
Williams, Ryan	University of Wyoming	GE
Cody, Paul	Washington University St. Louis	Flex Energy

Summary

The UTSR Program is alive and well, developing both technology and people for the benefit of the gas turbine industry