Deposition of Particulate from Coal-Derived Syngas on Turbine Blades with Film Cooling

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Background

- Alternate fuels are being considered to produce syngas to replace natural gas in power turbines
- Negative effects of deposition on components and gas turbine performance
- Heavier reliance on innovative film cooling strategies: internal cooling and film cooling

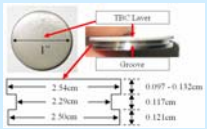
Objective

- Experimentally evaluate the influence of film hole shape, blowing ratio ,TBC and spacing on the formation of deposit from coal particulate
- Quantify the film cooling effectiveness and the heat transfer coefficient using a CFD model

Experimental Method

Film Cooling Art

C-TBC

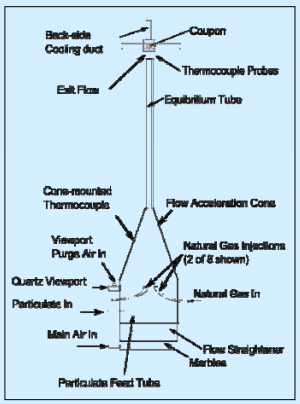


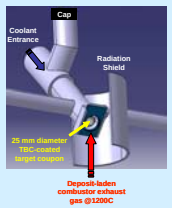
C-M1

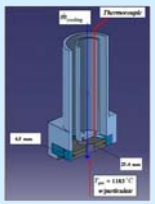
C-M2

- **C-M1,** Only superalloy,3 holes, dx1.5mm, 3d spacing, cylindrical
- **C-M2,** Only superalloy,3 holes, dx1.5mm, 3d spacing, shaped
- **C-TBC,**TBC on superalloy, 5 holes, dx1mm, 2.25d spacing, cylindrical

Research Facility



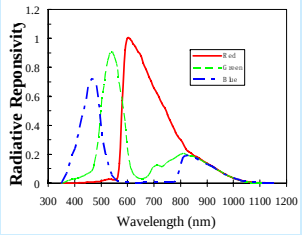




- Exit velocities up to 300m/s
- Gas temperature of 1183℃
- Match net particle throughput

8000hrs x 0.1ppmw ≈ 4hrs x 200ppmw

Temperature Measurement



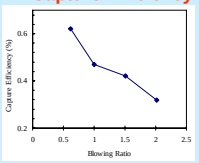
$$P_i = \int_{t_1}^{t_2} s_i \int_{\lambda_1}^{\lambda_2} \varepsilon_b I_{b,\lambda} \beta_\lambda \tau_\gamma d\lambda dt$$

- The surface temperature was measured by a RGB camera
- The camera is calibrated spectrally using a blackbody source
- Assume the surface a gray body

Result

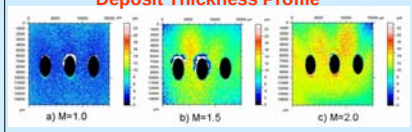
●C-M1

Capture Efficiency

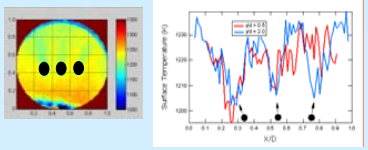


Deposit Patterning

Deposit Thickness Profile



Temperature Profile



- Testing Conditions: M= 0-2.0, 4 hrs tests, Density ratio=1.8-2.3
- Capture efficiency: The capture efficiency decreased by 50% with M increased from 0.6 to 2
- Deposit Thickness: The ridges are apparent at a blowing ratio of 2 but not apparent at M = 1
- Temperature profile: three temperature valleys are easily visible

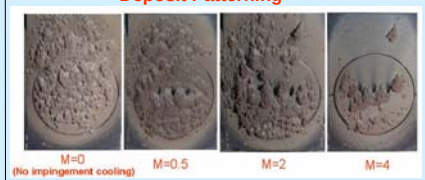
●C-M2

Deposit Patterning

- Deposit Patterning The area affected by the shaped hole coolant is larger and reduces the surface deposit more efficiently
- Temperature Profile uniform temperature in the entire lateral region downstream

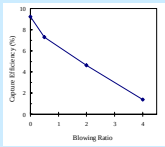
●C-TBC

Deposit Patterning



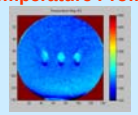
Testing Conditions:
M= 0-4.0, 1 hr test,
Density ratio=1.8-2.3

Capture Efficiency

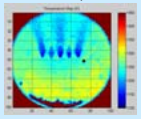


- The capture efficiencies for the TBC samples are much higher than that of metal, coincided with the temperature map

Temperature Profile

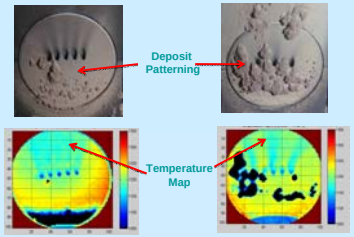


Bare metal coupon at M=2.0



TBC coupon at M=2.0

●Hole Spacing



- Close hole spacing increased the coolant coverage greatly to reduce deposition in the coolant path

Conclusion

1. For C-M1, the deposits formed ridges downstream of coolant injection, coincided with the temperature map.
2. The capture efficiency decreased with the increase of blowing ratio
3. The shaped holes have more span-wise coverage than the cylindrical holes and reduce deposition effectively
4. The capture efficiencies for the TBC coupon tests conducted here were greater than for the bare metal coupon
5. The non-uniformity in surface temperature on TBC sample increased with deposit thickness and with blowing ratio
6. Close hole spacing increased the coolant coverage greatly to reduce deposition in the coolant path

Future Work

- Determine further how the deposit is affected by holes spacing and trench configuration
- Develop a deposition model coupled with a simple film cooling scheme to simulate experiment conditions
- Use CFD model to quantify film cooling effectiveness and heat transfer coefficient and predict deposition at the varying conditions

Acknowledgments

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