EBC and Material Requirements for Microturbines – A Detailed Analysis

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Advantages & Disadvantages
MT Environment

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- **Advantages**
  - Overall PR's are low - 3:1 to 8:1
  - Recuperator, rather than fuel, is source of ~ 1/3rd heat gain
  - Air bearing equipped machines cool rotor bore/center
- **Disadvantages**
  - Natural gas fuel raises water partial pressure
  - Operating lifetimes 8000 to 30,000 hours
  - Continuous use prevents renewal of stable oxide film

Recession – P and V Effects

$$\text{Recession rate (um/hr)} = \frac{512 * \exp(-111000/(8.314*T)) * v^{1/2} * P_{H2O}^{2}}{P_{total}^{1/2}}$$

Where T = temperature in Kelvin

v= velocity, m/s

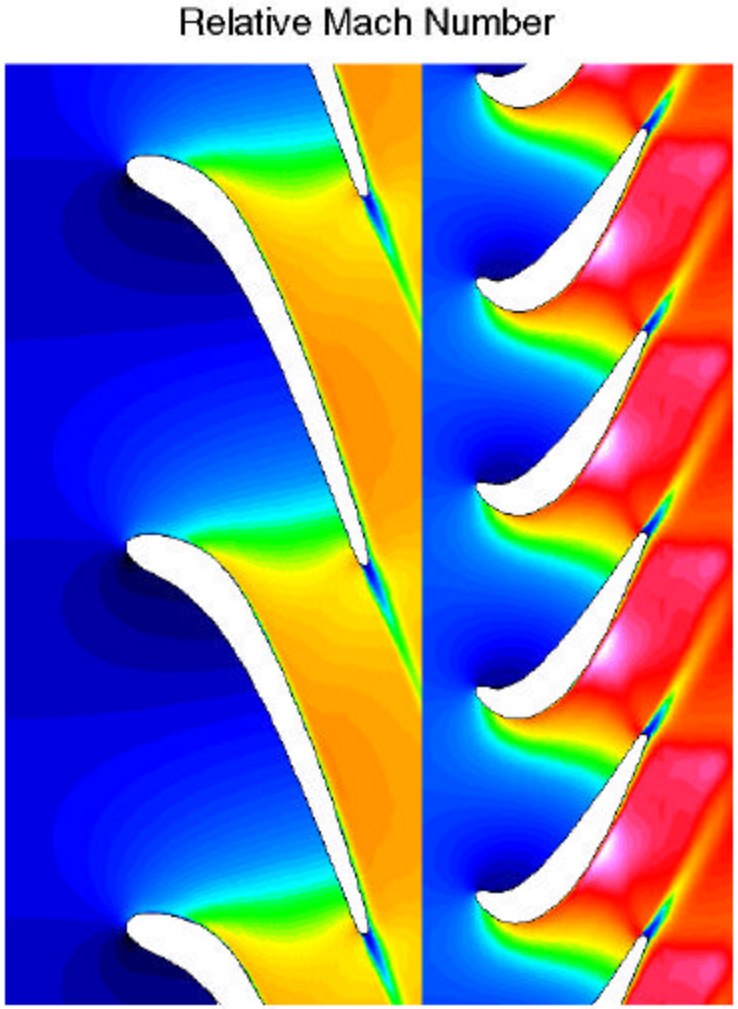
P = water vapor and total pressure in atmospheres

After M. Ferber, et al. adaptation of NASA/J. Smialek equation for silicon based ceramic recession

Velocity in High Turbine Changes Rapidly

- Rapid velocity increase results in pressure decrease

Vanes – Stationary reference frame

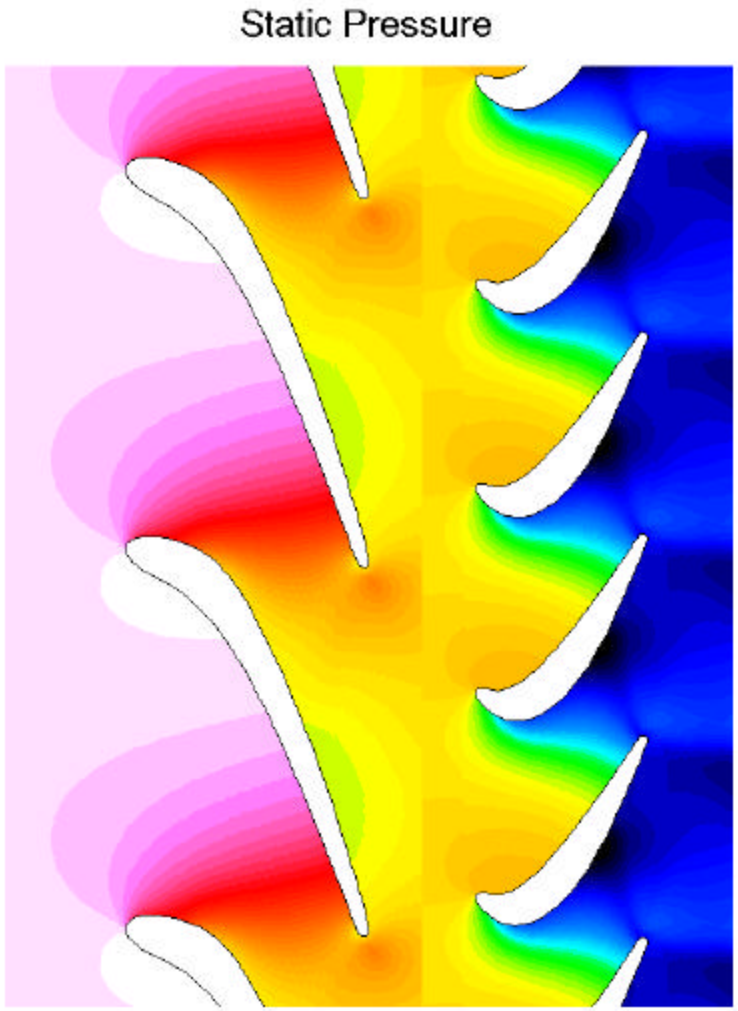


Blades – Rotating reference frame

Pressure in High Turbine Changes Rapidly

- Velocity changes & Work Extraction drop pressures

> 7 Atm.



< 3 Atm.

Temperature Decreases Rapidly

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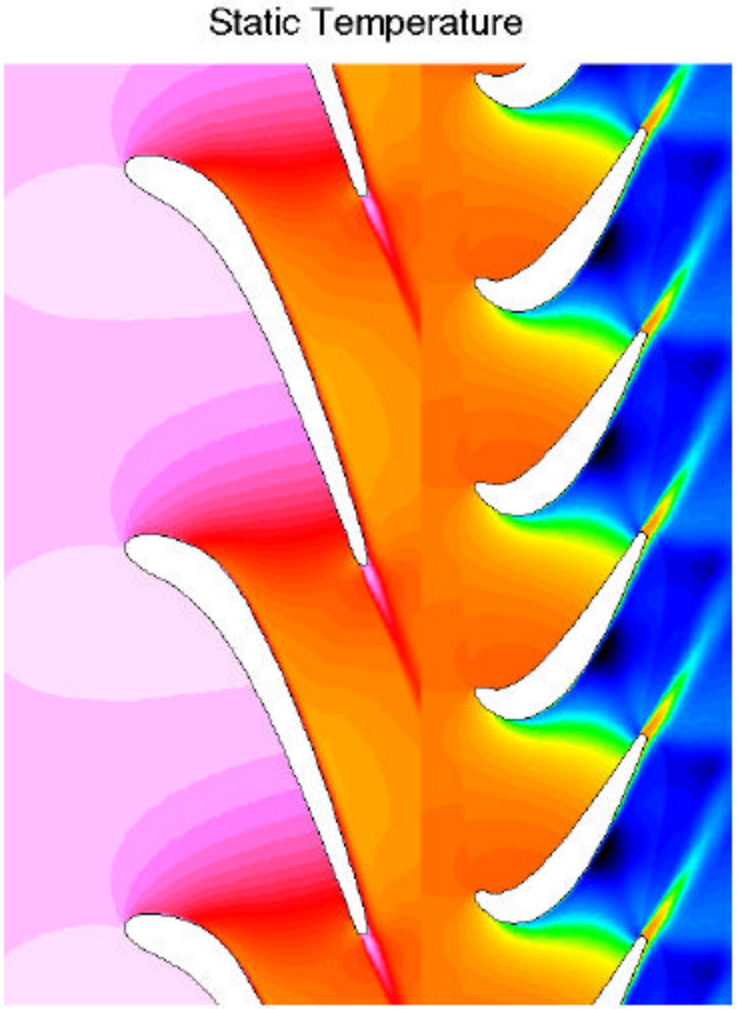
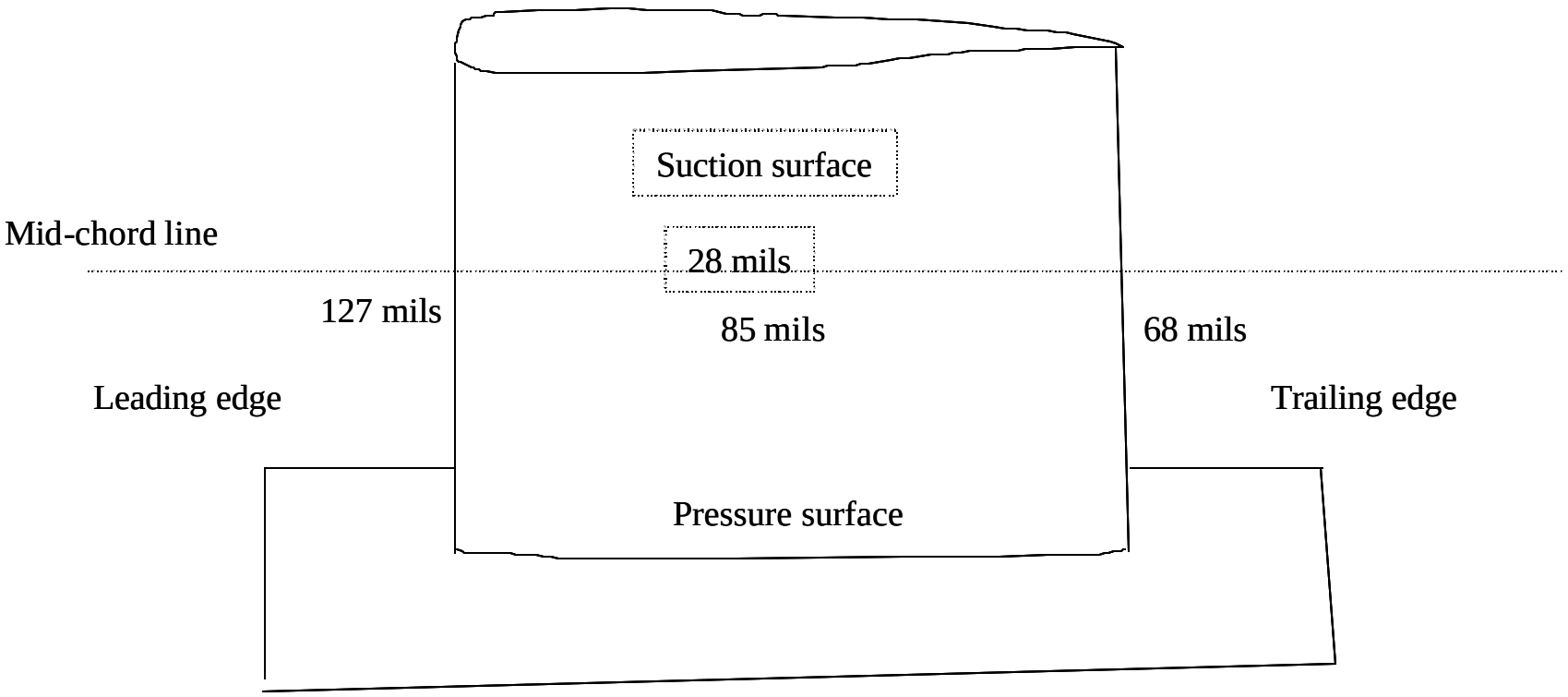
Delta T > 250ºC



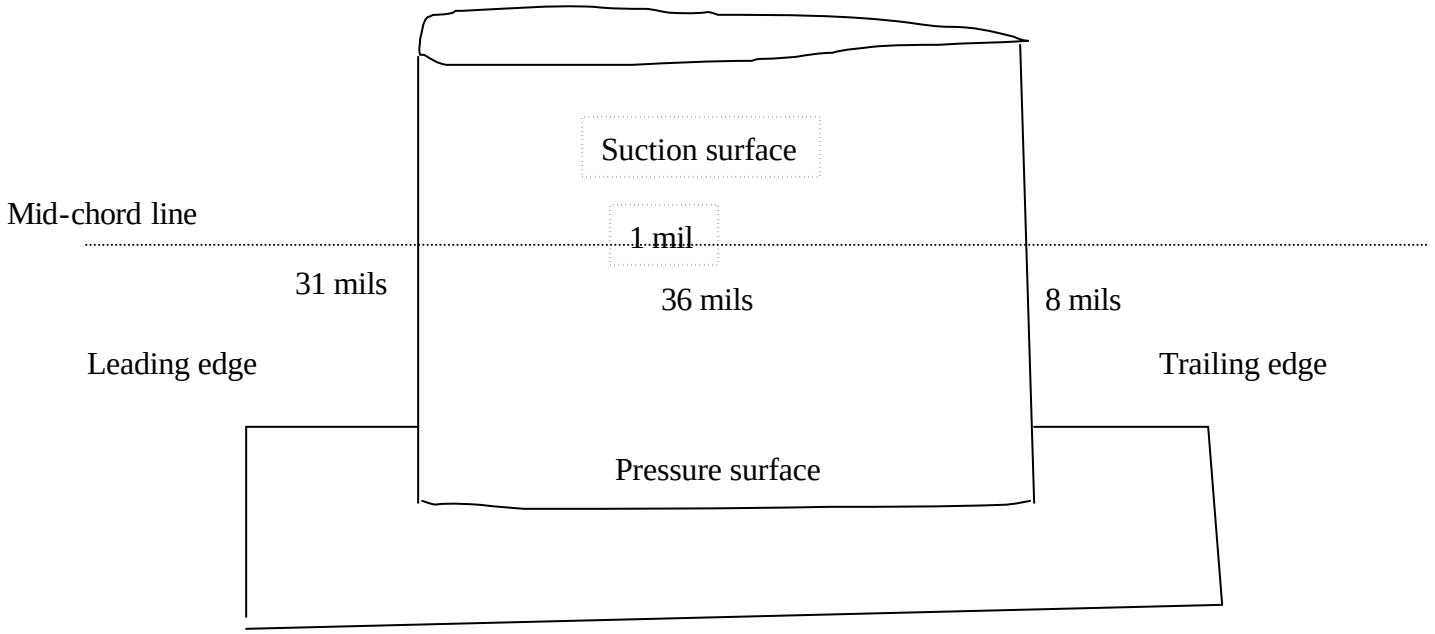
Recession Prediction – ST5 Vane

Predicted recession of Si_3N_4 vane after 25,000 hr in microturbine environment



Recession Prediction – ST5 Blade

Predicted recession of Si_3N_4 <u>BLADE</u> after 25,000 hr in microturbine environment



EBC's on Blades - Issues

- Foreign Object Damage/Erosion – especially leading edge
- Parasitic pull load
- Creep (coating)
- Blade tip rub
- Blade tip recession/concomitant performance loss
- EBC's prime reliant in microturbine application (current path)

Turbine Protection Needs

- Blades/Rotors - Greater oxidation resistance from base material
  - Must tolerate small area EBC spall/erosion
  - Increased toughness to reduce sensitivity to oxidation pits formed due to EBC defects/spalls/FOD events
- Blades/Rotors - EBC's still required for long life
  - Unlikely that material with "No EBC Needed" oxidation resistance will have requisite strength
  - Blade tips are a special case/need attention
- Vanes – EBC coated silicon nitride may be viable
  - Effect of EBC spall/erosion/crack less significant?
- Tip Shrouds
  - Abradable EBCs needed
  - Blade tip/shroud & their respective EBCs must be considered as a system

Conclusions

- P, T & V all change rapidly throughout the turbine hot section
- These changes, along with functional aspects of each turbine component, require consideration in environmental protection
- A systems approach – Base material as well as EBCs, are required to meet goals (particularly for blades/rotors)