Thermal Barrier Coating Applied to the Structural Shroud of the Inside-Out Ceramic Turbine

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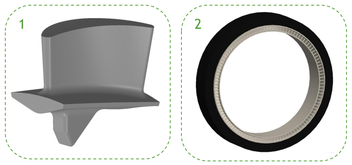
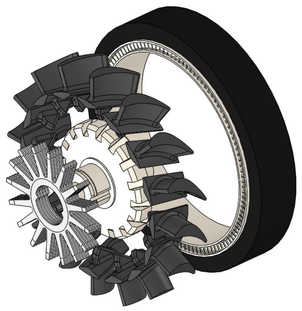
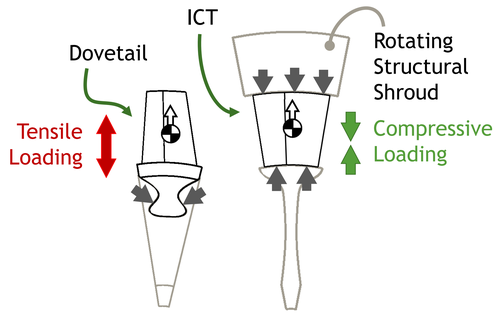
Does the ICT configuration support TBC?

What is the Inside-Out Ceramic Turbine? ICT

The ICT rotor configuration converts compressive loading in ceramic blades[1] to hoop stresses in an air-cooled rotating composite structural shroud[2]



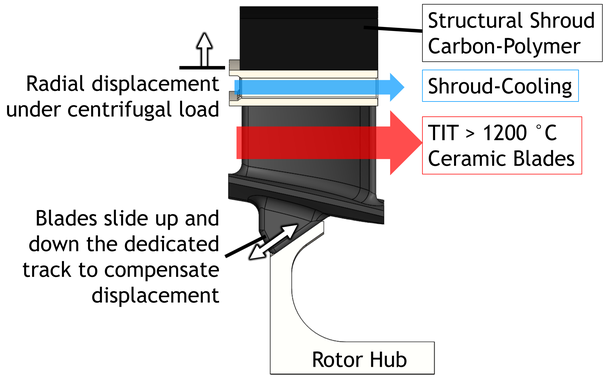




Motivation

TIT

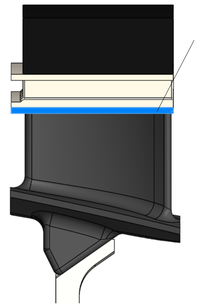
- The composite matrix limits Turbine Inlet Temperature, Tmax ≈ 320 °C
- Cooling flow significantly reduces cycle efficiency and counteracts TIT gains
- Relatively cold blade induces local stresses

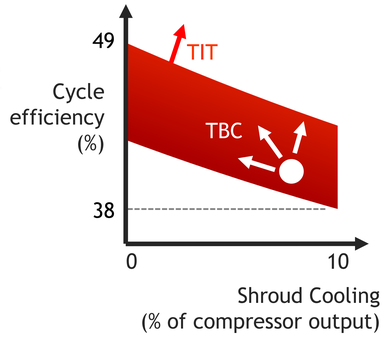


TBC

Thermal Barrier Coating in the ICT could

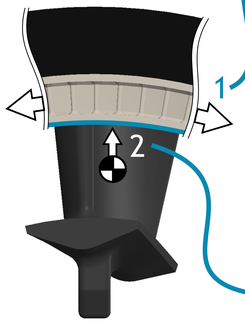
1. Reduce cooling requirements
2. Increase TIT capability
3. Eliminate hot spots in cooling ring
4. Keep the ceramic blades at a higher operating temperature



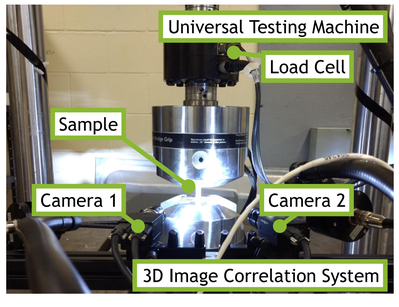


Approach

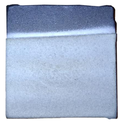
ICT Loads

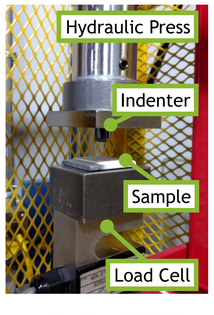


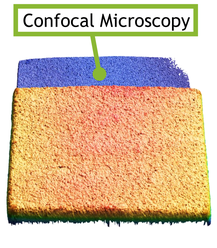
1. Hoop Strain



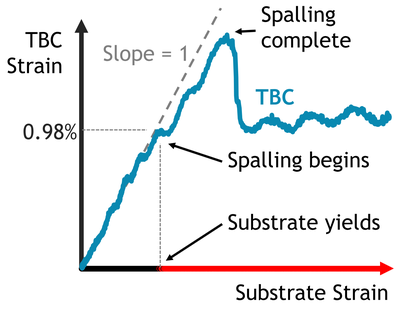
2. Blade Indentation

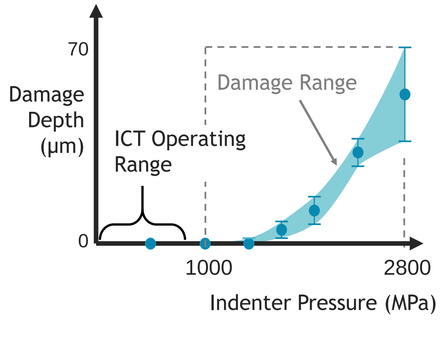






Results





In-plane compliance

TBC adheres to substrate until yield, with no effect on elastic properties

So what?

The entire elastic range is available for designing the cooling ring

High out-of-plane strength

Tested TBC resists indentation up to 1000 MPa

So what?

TBC will withstand the centrifugal loading of the ceramic blades

Rotor Testing

Test conditions

- 5 minutes at TIT = 900 °C
- 3D-printed Inconel 718 Blades
- 1mm TBC thickness
- 80 000 RPM

Test Results

- ✓ 50% reduction in cooling flow
- ✓ No damage to TBC
- ! Composite hoop split due to added mass

Conclusions

The Inside-Out Ceramic Turbine configuration **supports TBC** thanks to its **orthotropic** behaviour

TBC should allow the use of lightweight Ti alloy shroud-cooling, allowing **higher RPMs** and **lower thermal stresses**

Acknowledgments
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