Improved Combustion Liner Seal

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Mechanical Engineering CAL POLY

Solar Turbines A Caterpillar Company

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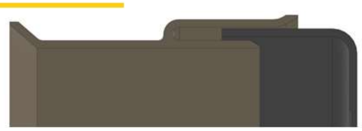
Ellie Cruse and Zachary Norris, CNC Machinists
Troy Cracroft, JETSEAL Contact

Background



Section View of Solar Turbines' Current Combustor Liner Seal ("Fishmouth" Seal)

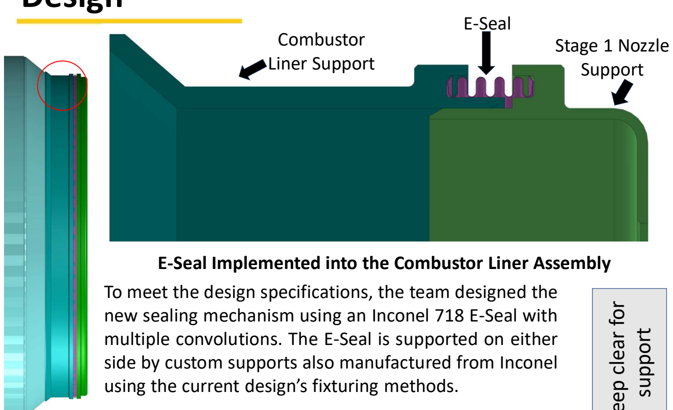
The current sealing method leaks cooling air into the combustion chamber due to manufacturing inconsistencies and radial thermal expansion of the two contacting surfaces. The project goal is to design an improved mechanical seal between internal combustion gases and external cooling air at the combustion liner to turbine nozzle interface. This seal must function through the entirety of the turbine's operating environment, including a cold no-load and hot full-load operation, and be designed to be assembled and serviced within current Solar Turbines' practices.

Design Specifications

List of Product Requirements per Solar Turbines' Needs

Spec. No.	Description	Requirement/Target
1	Size	Nominal 37-inch seal diameter
2	Lifespan	30,000 hours of continuous operation (60,000 ideal)
3	Cycles	5000 thermal cycles
4	Material Temperature Rating	1200°F
5	Sealing	No leakage
6	Serviceable	Accessible during field maintenance
7	Assembly	Capable of attaching to turbine in standard assembly process
8	Part Count	2-part count seal system
9	Safety Factor	0.85 S_y of any material
10	Axial Thermal Expansion	0.034 inches decompression at full-load
11	Radial Thermal Expansion	0 inches relative to E-seal end of combustor liner and nozzle supports

Design

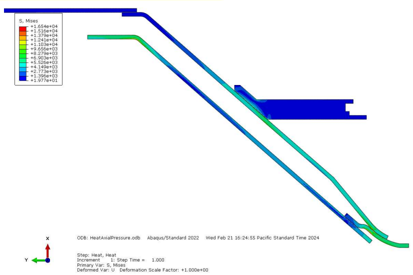


E-Seal Implemented into the Combustor Liner Assembly

To meet the design specifications, the team designed the new sealing mechanism using an Inconel 718 E-Seal with multiple convolutions. The E-Seal is supported on either side by custom supports also manufactured from Inconel using the current design's fixturing methods.

Keep clear for support

Analysis



FEA of the Combustor Liner Support

Due to the size and applicable testing available for the project, a significant amount of design verification was done through analysis before developing a functional prototype.

The team conducted FEA on the redesigned components and surrounding regions to ensure they could withstand the high temperature and produced stress in the turbine. Hand calculations were performed to ensure the design met the fatigue and creep failure requirements.

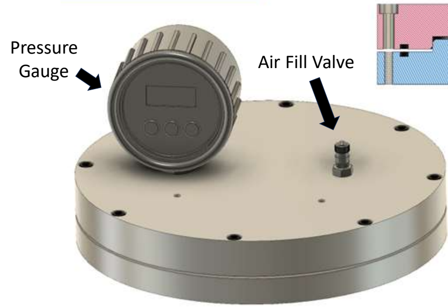
Thermal Creep Hand Calculation for Extended Life

Material	Mitigation	Peak Average Stress (Ksi)	Hours to 0.1% Creep*
Haynes 230	Reduced Load	6.91	74900

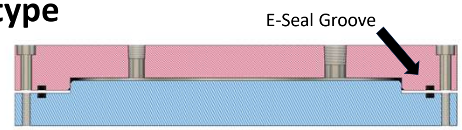
Thermal Creep Hand Calculation Results

Material	Part	Peak Average Stress (Ksi)	Hours to 0.1% Creep*
Alloy 718	Liner Support	2.1	4.86E+11
Alloy 718	Nozzle support	3.9	1.65E+11
HastX	Combustion Liner	7.3	1.92E+06
Haynes 230	Combustion Liner	8.2	12000

Manufactured Prototype



Final Assembly of the Prototype



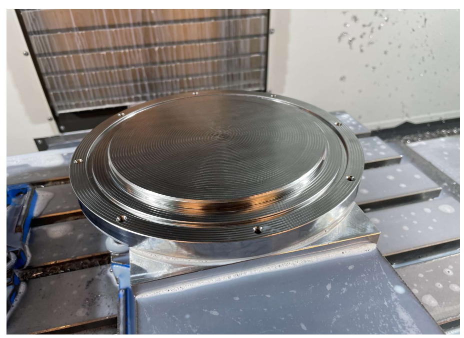
Section View Showcasing the Internal Design of the Prototype

The prototype manufactured for testing was a small-scale fixture with geometry following the seal manufacturer's guidelines. The small-scale model was chosen for manufacturing feasibility and sized by a small representative seal donated by JETSEAL. The objective of the prototype was to simulate leak environments to determine the best application of the design and evaluate potential leak rates and issues.

Manufacturing

A prototype for the sealing mechanism was CNC machined out of 17-4 stainless steel. Various fixtures were manually machined out of aluminum and steel as necessary.

Tapping Holes in the Top Plate



The Bottom Plate of the Prototype In the CNC Machine

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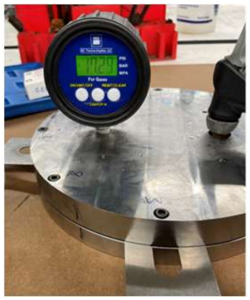
Testing

1. Pre-Cycled Pressure Decay
2. Load Frame Cycle
3. Post-Cycled Pressure Decay

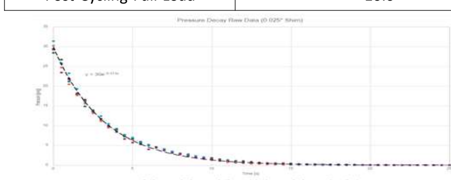
Cyclic Load Frame Testing Setup

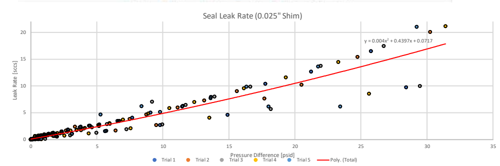


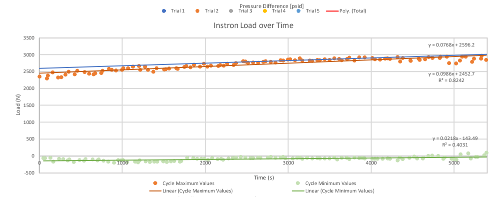
Pressure Testing Setup with 0.025" No-Load and 0.050" Full-Load Shims

Results

Test Scenario	Leak Rate at 14 psig (sccs)
JETSEAL Specified	0.01
Pre-Cycling No-Load	0.5
Pre-Cycling Full-Load	3.5
Post-Cycling No-Load	2.0
Post-Cycling Full-Load	10.0







Conclusion

The team has several recommendations for the sponsor. A manufacturing method that leaves a circular lay surface finish is very critical. It is also highly recommended to follow specifications set by the manufacturer of the seal, as well as source a coated seal to loosen surface finish requirements. To meet lifetime length requirements, a support material matching the hardness of the seal material is necessary.