U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

SETO CSP Program Summit 2019

Experimental and Numerical Development of GEN3 Durability Life Models

DoE Award # DE-EE0008370

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Motivation

- In the solid media pathway for CSP systems, damage to the system components and attrition of particles results in particle loss, changes in particle morphology, and ultimately changes in thermal performance from the resulting erosion to the system.
- Erosion and attrition could lead to significantly increased operational costs (repair or replacement of the particles, or underlying containment materials that are susceptible to erosion damage).
- The attrition and erosion of materials can potentially affect underlying thermophysical properties, reduction in heat transfer and potential changes in the optical properties, which could result in a decrease in thermal efficiency of the GEN3 plant.

Objective

- Develop a broad understanding of mechanical durability within CSP systems that can be used to determine component lifetime and degradation.
- Critically, we will combine this component information with an understanding of the system behavior to characterize the resulting impact on system performance.
- Develop GEN3 Durability model that will provide outputs that can model the optical degradation of particles over plant lifetime, total particle attrition, and substrate erosion.

Existing Components/ Materials
- Particles
- Containment

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Particle Durability
- Thermal/UV cycling
- Abrasion attrition
- Impact attrition
- Mechanical Property testing

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Substrate Durability
- Abrasion attrition
- Impact attrition

→

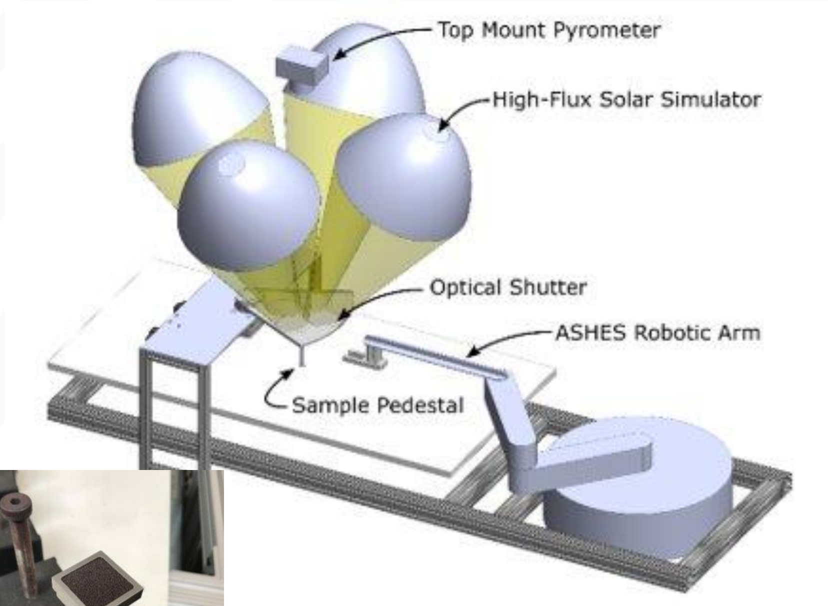
GEN3 Durability Model
- Temperature Dependence
- Particle Mechanical Properties
- UV Dependence
- Particle Loading
- Operating Conditions

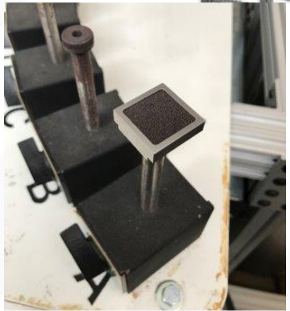
Key Activities

- Development of experimental facilities
- Mechanical property characterization under relevant GEN3 conditions >700 C
- Complete testing of 3 candidate particles and containment materials
  - Particles – Carbo ID50, sintered bauxite, sand
  - Containment materials – SS316, Inconel 740H, refractory firebrick
- Development of comprehensive durability model:
  - Wear rates
  - Optical property changes

Current Accomplishments

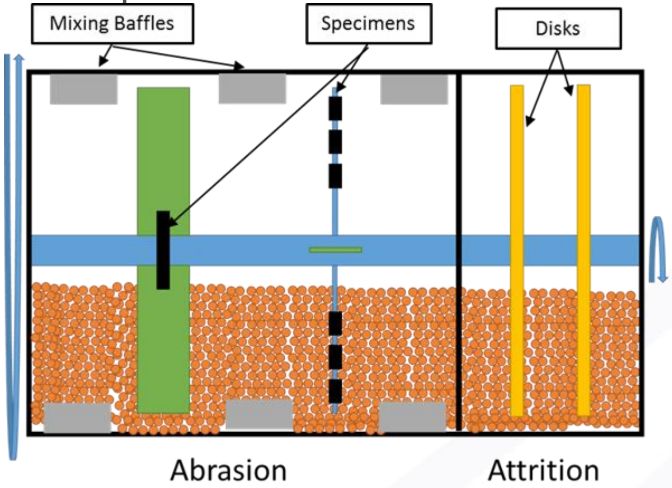
Task 1 : Developing the capability for testing particles in the ASHES system





Current Accomplishments

Task 2 : Design and build experimental rig for particle and containment abrasion capable of 700 C operation



Specimen mounted on shaft

Speed Controlled motor

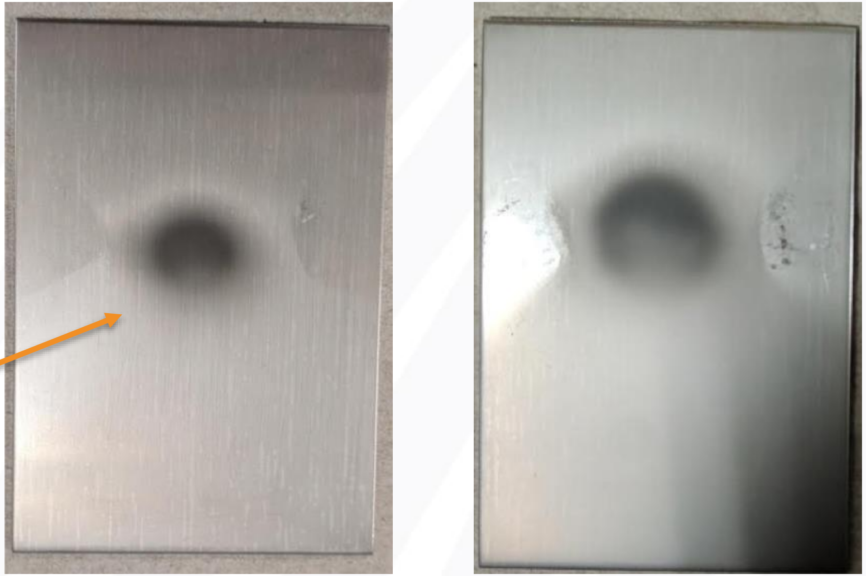
Current Accomplishments

Task 2 : Design and build experimental rig for particle and substrate abrasion capable of 700 C operation

Acrylic prototype of Attrition setup

Current Accomplishments

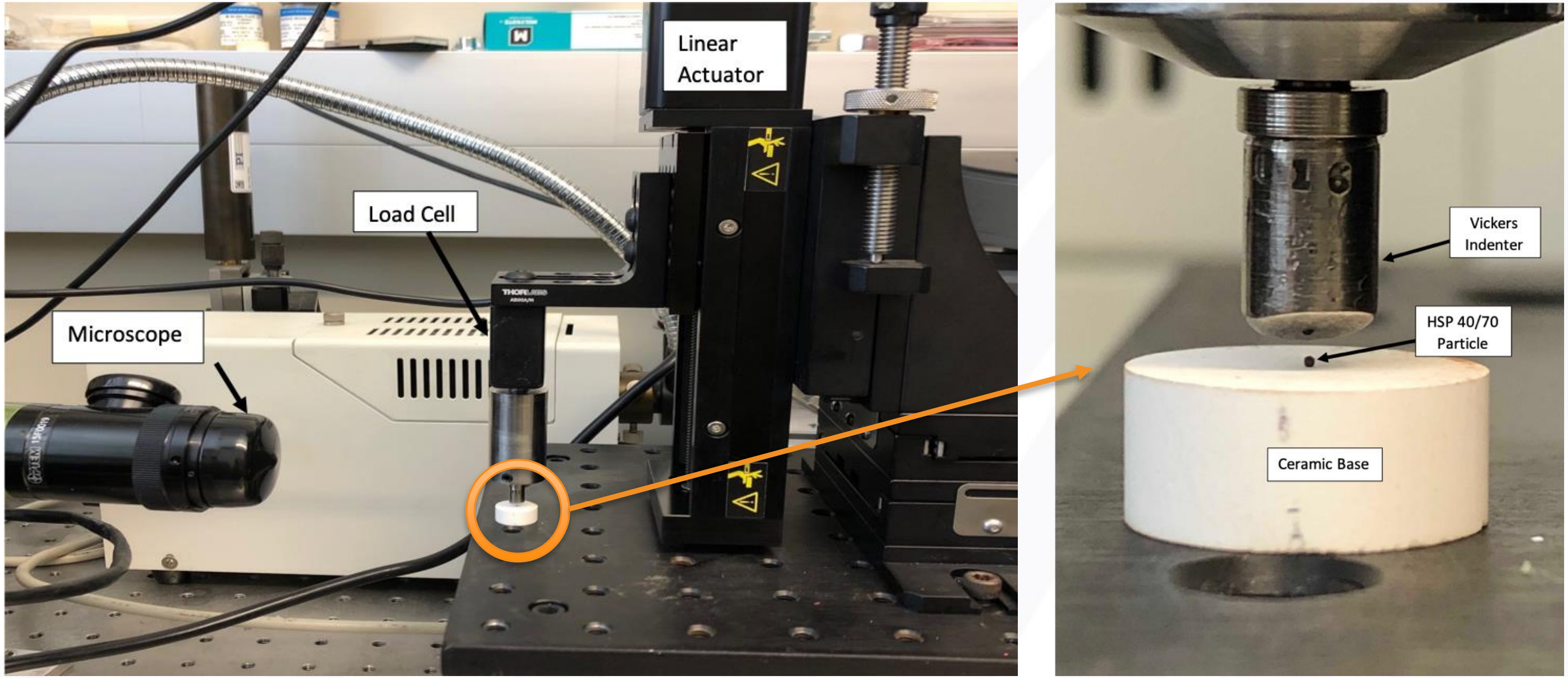
Task 3 : Design and build system capable of delivering 0.1-10 m/s of particles at 700 C for impact attrition and erosion



Stainless steel coupon after being impacted by 50 Kg (left), and 300 Kg (right) of HSP 40/70 in hourglass apparatus

Current Accomplishments

Task 4 : Design and build single particle testing system that can test individual particle mechanical properties



Experimental set up to test the mechanical properties of particles.

Next Steps

- Build a large scale experimental setup for the particle Abrasion and Attrition tests.
- Build a large scale experimental setup impact abrasion and attrition on substrate material.
- Conduct abrasion and attrition tests at temperatures of interest (T>700°C)
- Cycle samples to 30,000 hours at high temperatures.
- Build durability models that can predict optical degradation of particles over plant lifetime, total particle attrition, and substrate erosion.

Investigators

- Dr. Todd Otanicar: PI, Associate Professor of Mechanical Engineering at The University of Tulsa, Director of the Energy and Nanoscale Transport Laboratory and the Outdoor Solar Test Facility.
- Dr. Michael Keller: Co-PI, Associate Professor of Mechanical Engineering at The University of Tulsa, Director of the Advanced Composite Materials Laboratory
- Dr. Siamack Shirazi: Co-PI, Professor of Mechanical Engineering at The University of Tulsa , Director of the Erosion/Corrosion Research Center (E/CRC).
- Dr. Kevin Albrecht: Co-PI, Senior Member of the Technical Staff at Sandia National Labs.
- Dr. Nipun Goel: Post-doctoral researcher at The University of Tulsa.

- Graduate Students: Taylor Brown, Evan Gietzen, JT Stancil

Questions?