Experimental and Numerical Evaluation of a Small Array of Ceramic Foam Volumetric Absorbers

Dr. Fritz Zaversky
fzaversky@cener.com

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Project objectives

- Increase plant efficiencies and reduce levelized cost of electricity (LCOE) by proposing an innovative plant concept
- Downsized heliostat for mass production + smart calibration system
- Validating the most critical components in the relevant environment
Solar-driven hot air turbine prototype is going to be installed at the PSA

An open volumetric solar receiver charges a regenerator

The regenerator is pressurized and discharged, driving the turbine
Solar receiver – SiC foam absorber

- Open volumetric air receiver
- SiC foam absorber
- ≈ 300 kW thermal
- 0.7 m² aperture area
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- 30 PPI, frustum 10x10 mm, 92.0% porosity, 65 mm thickness (A)
- 30 PPI, frustum 10x10 mm, 89.5% porosity, 65 mm thickness (B)
- 30 PPI, frustum 20x20 mm, 89.5% porosity, 65 mm thickness (C)
- 30 PPI, frustum 10x10 mm, 89.5% porosity, 30 mm thickness (D)
• Cooling water flow in the heat exchanger was activated (full constant flow).
• Next, the air blower was switched on and quickly ramped to full load (100%).
• Once the air flow through the experimental loop was established, the chosen heliostats were focused one after another in time intervals between 2 and 5 minutes. Note that only a fraction of the heliostat field (31 heliostats of the SSPS-CRS tower) was used.
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Conclusions of experimental activity:

- Unfortunately, the measurement uncertainty was too high to provide a clear distinction between absorber samples.
- No final absorber geometry could be selected purely based on the experimental activity.
- Nevertheless, the foam absorber samples withstood operating conditions under highest temperatures (up to 900°C). No fracture of the absorber samples was observed.
The fundamental aim of the rear absorber profile is to achieve a homogenous velocity profile across the cup’s aperture in order to guarantee homogenous cooling, avoiding hot areas at low flow velocities.

The aim was to find the best compromise between simple design (foam geometry manufacturing restrictions) and homogeneous flow velocity distribution.

Air velocity profile depends on frustum shape
So does the temperature distribution in the foam

• Frustum shape

(a) 10mm 10mm
(b) 10mm 10mm
(c) 10mm 10mm
(d) 15mm 10mm
(e) 10mm 5mm
Numerical evaluation of foam geometry

(a) Foam absorber solid phase (ceramic material) temperature

(b) Foam absorber fluid phase (air) temperature
Intermediate-scale 2 x 2 cup array test was possibility for foam parameter selection before manufacturing and installing the final 300 kW_th CAPTure receiver at the same location.

It could be shown that the ceramic foam absorber samples withstood operation under highest temperatures (up to 900 °C) without fracture.

However, no difference in absorber sample performance could be detected due to limited measurement capabilities.

Five different absorber shapes have been evaluated numerically, including different frustum shapes and also a simple flat foam geometry.

Geometry option (a) (frustum 10 x 10 mm, 30 mm thickness) has been selected for the final CAPTure receiver prototype.
CAPTure prototype:

- ≈ 300 kW thermal
- To be installed at CRS tower by the end of the year
- 1 year solar testing operation until end of 2019
- Should demonstrate the operation of a solar-driven gas turbine, powered by an open volumetric air receiver
- And consequently the feasibility of a solar-powered combined cycle
Thank you for your attention!

Dr. Marcelino Sanchez
msanchez@cener.com

Dr. Fritz Zaversky
fzaversky@cener.com