Hydrodynamic, Thermal and Optical Evaluation of Ceramic Foam Solar Absorbers

SolarPACES

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1. Introduction

The development of advanced solar receivers is essential for enhancing the efficiency of concentrated solar thermal (CST) technologies. This study, conducted within the Horizon Europe ASTERIx-CAESar project (funded under GA 101122231), evaluates volumetric solar absorbers made of ceramic foam (120 mm x 120 mm aperture) through an extensive experimental campaign at both the cup and absorber level. The main objective is the analysis of the hydrodynamic, thermal, and optical behavior of 9 ceramic foam absorbers under real experimental conditions solar furnace SF60 at the Plataforma Solar de Almeria (PSA). For this purpose, a set of 9 absorbers varying porosity and geometry, and 3 cup orifices were designed and tested at PSA. The testing procedure was structured into 3 experimental campaigns, each focusing on specific aspects of the system's performance.

2. Methodology

The study followed a sequential experimental methodology structured in three phases:

1. Cold flow tests: Evaluating the impact of cup's outlet diameter variation on airflow regulation.
2. Thermal performance assessment: Measuring absorber efficiency under varying solar flux conditions and target fluid outlet temperature.
3. Optical characterization: Analyzing changes in the absorbers' optical properties due to thermal exposure.

This systematic approach provides a comprehensive assessment of the factors affecting absorber's efficiency and durability.

3. Results

3.1 Cold tests on airflow regulation

Phase 1 focused on cold tests to assess the influence of the cup's outlet diameter on air mass flow rate (Fig. 1). To isolate the cup's effect, experiments were conducted without solar irradiation and without volumetric absorber. Airflow regulation was analyzed systematically using blower speeds of 100%, 75%, 50%, and 25%, along with 3 outlet diameters of the cup (30 mm, 40 mm, and 60 mm). Results showed a clear correlation: reducing the outlet from 60 mm to 40 mm (56% area reduction) decreased airflow by 10%, while a further reduction to 30 mm (75% area decrease) led to a 30% drop. These findings highlight the critical role of the cup geometry in airflow control.

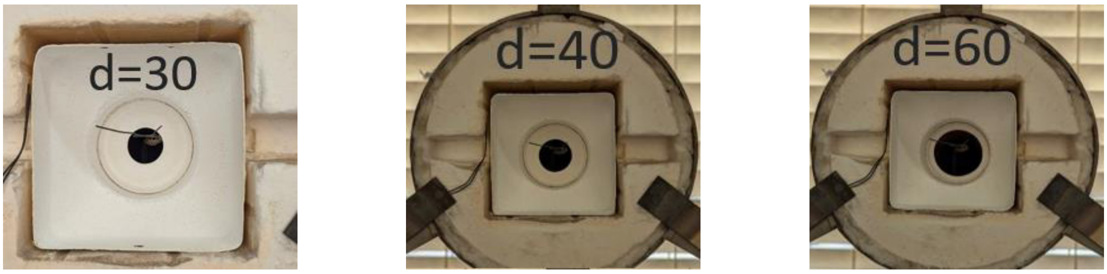

Fig. 1: *Cups orifices at the outlet opening: (left) 30 mm, (center) 40 mm, (right) 60 mm.*

3.2. Thermal performance assessment

Phase 2 evaluated the thermal performance of the 9 absorbers using a cup with a 60 mm outlet opening (see Fig.1-right). Each absorber was tested under 3 shutter apertures of the solar furnace (20%, 25%, 30%), corresponding to incident flux levels of ~550–1100 kW/m², and 3 target air outlet temperatures (600ºC, 700ºC, and 800ºC). The air mass flow rate was adjusted while keeping the shutter aperture constant. After each test, solar flux characterization was performed. Each absorber was tested 4-5 hours to ensure steady-state conditions. Preliminary results identified R1-169 as the most efficient absorber. Fig. 2 compares the relative efficiency of selected absorbers against R1-169 for the different working conditions.

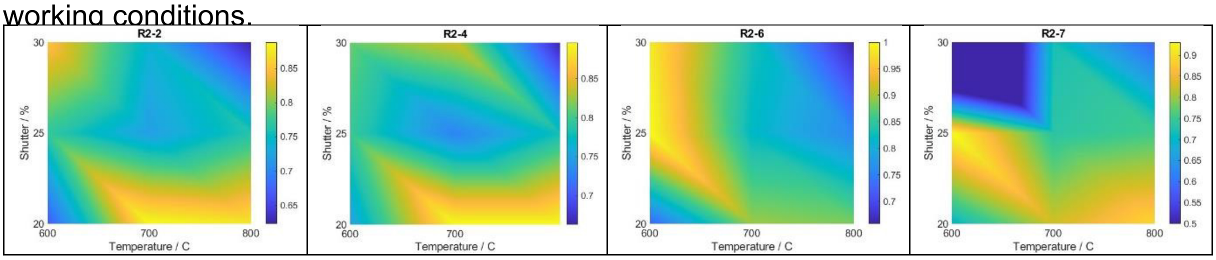

Fig. 2: *Relative efficiency of samples R2-2, R2-4, R2-6, and R2-7 in relation to absorber R1-169*

3.3. Optical characterization

Phase 3 analyzed the solar absorptance and thermal emittance of the 9 absorbers before and after thermal testing, as these properties play a key role in thermal performance by affecting heat transfer and losses. Given the absence of standardized methods for porous materials, a preliminary assessment was conducted to establish baseline values. Solar absorptance was measured in 9 zones of each absorber to capture potential variations due to differing exposure to concentrated solar radiation. Initial results show negligible changes after thermal exposure as presented in Table 1, though further validation is needed. The full study will include thermal emittance measurements to better understand heat loss mechanisms.

Table 1. *Solar absorptance before and after the test for R1-169, R2-4, R2-6*

Absorber	**R1-169**	**R2-4**	**R2-6**
Average solar absorptance before testing	0.964	0.967	0.970
Average solar absorptance after testing	0.965	0.969	0.971

4. Outlook

The experimental campaign provided valuable insights into the behavior of volumetric solar absorbers under realistic operating conditions. A detailed analysis of the results will guide the consortium in selecting the optimal cup outlet diameter, confirming the most efficient absorber, and refining optical performance predictions for the full receiver.

Future thermal tests will be conducted using the best performing solar absorber while evaluating different outlet orifice configurations. The results and conclusions will be presented at the conference, contributing to the final design of the ASTERIx-CAESar receiver.