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Experimental results of gradual porosity wire mesh absorber for volumetric receivers

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Abstract

Concentrated Solar Power (CSP) market is focused in the cost reduction by means of increasing efficiencies and reducing the investment, installation and, operation and maintenance costs. In Concentrated Solar Power with Central Receiver (CR) technologies, one option for increasing efficiency is to raise the temperature of the working fluid. The CSP-CR technology working with volumetric air receiver shows a high potential to improve efficiencies by allowing higher operating temperatures (above the limit of commercial power tower plants).
However, most of the different volumetric receivers tested during the last three decades did not match the predicted nominal conditions, working at lower efficiencies than expected. Other challenges still remain unsolved, like absorber durability, and the specific cost.
In order to identify high-efficient configurations and geometries for the absorbers used as volumetric receivers, CIEMAT-PSA (funded by SOLGEMAC project) has developed a lab-scale test bed used for the evaluation of open volumetric receivers.
The main goal of the installation is to identify different configurations and geometries that improve the thermal efficiency of the reference open-loop volumetric receivers: Phoebus-TSA for metallic materials and SOLAIR for ceramic ones.
The initial tests of the installation are focused on characterized the TSA and the SOLAIR absorbers. Then, a comparison with the newer designs will be made in order to improve the reference absorbers.
First results with the SOLAIR absorber made of recrystallized SiC with an open porosity of 49.5 %, for a mean air outlet temperature varying from 266-to-623 ºC, moves from 89-to-56% thermal efficiency.
For the newer designs, CIEMAT-PSA has AISI 310 commercial wire meshes with different characteristics. The wire ranges from 0.13-to-1.00 mm, and the mesh size varies from 0.20-to-4.00 mm. With different combinations of the meshes, several prototypes will be analyzed.

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1. Introduction

The increasing problems of CO_2 emissions and the fossil fuel costs have strengthened interest in alternative, nonpetroleum-based sources of energy. Among the variety of technologies of Solar Thermal Power Plants (STPP), Central Receiver systems with open volumetric absorber appear as a promising scheme that could increase receiver and BOP efficiencies both reducing radiative thermal losses, and raising the temperature of the Heat Transfer Fluid (HTF).

Volumetric receiver development dates back to 1983 with first prototype [1]. The highly porous structure of volumetric receivers may be metal or ceramic. Since ceramics are the most appropriate materials for achieving the highest air temperatures, this is the most suitable option when temperatures above 800ºC are necessary. On the other hand, metallic receivers allow higher heat transfer between air and the structure and quicker response. For CR systems with open volumetric absorber there are two reference receivers: TSA for metallic materials and SOLAIR for ceramics [2].

The TSA absorber tested in PSA was made up of Inconel 601 coiled knit-wire knitted packs. The main result of the tests carried out in 1993 was the ability to achieve the design absorber efficiency of 85% at 700ºC receiver air outlet temperature at an average flux density of 300 kW/m^2 and an air return ratio of 60%. The main conclusions from the tests of the 2.5 MW_{th} volumetric air receiver project were that the system control was able to maintain air outlet temperatures constant, the modular design would facilitate future plant scale-up, the ability to match the air flow distribution of the absorber with the incident flux distribution and the flexibility of the process [2].

The SOLAIR absorber tested in PSA was made of re-SiC with a porosity of 50%. The receiver was a modular absorber assembled from 270 ceramic cups made of SiSiC. The results showed that the efficiencies varied in the range of 70-to-75% at 750ºC receiver air outlet temperature for mean solar fluxes in the range of 370-to-520 kW/m^2 and an air return ratio of 50% [2]. In June 2006, it was decided to build a central receiver plant with volumetric receiver (SOLAIR technology) and thermal storage in Jülich, Germany. The aim of the project was to demonstrate this technology in a complete pre-commercial power plant for the first time [3].

In spite of this nice project results, most of the different volumetric receivers tested during the last three decades did not match the predicted nominal conditions, working at lower efficiencies than expected. In order to identify high-efficient configurations and geometries for the absorbers used as volumetric receivers, CIEMAT-PSA (funded by SOLGEMAC project) has developed a lab-scale test bed used for the evaluation of open volumetric receivers.

The main target of the facility is to identify different configurations and geometries that improve the thermal efficiency of the reference volumetric absorbers: TSA and SOLAIR. For that purpose, CIEMAT-PSA is developing with commercial AISI 310 different volumetric absorbers structures with gradual porosity.

Gradual porosity volumetric absorber is a promising innovation that addresses to solve the main thermal problems of this technology. The basic objectives of gradual porosity is to reduce the front surface of the absorber, which means lower radiative losses, and on the other hand, promote the basic principle of a volumetric which is the absorption of the radiation in the depth of the structure.

Nomenclature

CSP	Concentrated Solar Power (CSP)
CR	Central Receiver
STPP	Solar Thermal Power Plants
HTF	Heat Transfer Fluid
BOP	Block Of Power
P	Power (W)