HIGH PERFORMANCE FLAT PLATE SOLAR COLLECTOR BASED ON TRANSPARENT INSULATION WITH COLD PLATE-BASED ABSORBER

Summary

The aim of this work is the development of a highly efficient thermal Flat Plate Collector (FPC) based on Transparent Insulation Materials (TIM) on the cover. By insulating the collector's cover, the overall efficiency of the flat plate solar collectors will be increased, and it is possible to work at higher temperatures (90ºC) and capture a considerable amount of thermal energy in periods of low irradiation. This work is a progress of an already existent development by employing a high-performance hybrid absorber with enhanced heat transfer capability based on microchannel flat tubes. This improved absorber will be used to increase overall efficiency performance due to two positive effects: i) improved heat transfer coefficient between heat carrier fluid and absorber; ii) improvement of the compactness of the granular silica aerogel layer, to favor the efficiency of the FPC. Efficiency curves experimental results will be presented, and they will be compared with an already existent simulation model, to assess the improved results.

Keywords: FPC, silica aerogel, plastic TIM

1. Introduction

Transparent Insulation Materials (TIM) have already been used in the past years to enhance the performance of solar thermal FPC. Several configurations could be used: i) honeycomb plastic (Kizildag et al., 2022); ii) plastic slats; iii) multi-glazing; iv) silica aerogel (Svendsen, 1992) (Nordgaard et al., 1992). TIM increases the insulation level, thus reducing thermal loss due to heat conduction or convection, e.g., to the cover to decrease air convection between the absorber and cover glass. In addition, highly insulated covers protect against freezing risk in cold climates. As described above, the present project combines the use of glasses, plastic honeycomb structures, and silica aerogel optimally from a thermal and structural point of view. Other actions focused on the enhancement of the solar thermal collector efficiency are to improve the absorber performance through the following actions i. e. i) improving the surface treatment to enhance optical properties; ii) the modification of the working fluid (e.g., heat pipes); iii) mini/micro-channel; iv) geometry modification for increasing the heat transfer area (Santos et al., 2023).

The present work further develops the technological innovation of the European patent reference EP2522927A2. The patent refers to a composed transparent insulation made of glass, plastic honeycomb, and silica aerogel applied to the cover (Zheng et al., 2024) (see Fig. 1). The present work aims to improve this technology by using an advanced absorber will be designed based on a cold plate used for refrigerating batteries (see Fig. 2), which allow improved heat transfer capabilities (avoiding temperature differences due to fins in the absorber). Moreover, the compactness of the granular silica aerogel layer is expected to improve due to an improved absorber stiffness. Higher compactness of the granular silica will have a double favorable effect: i) improved thermal insulation capability of the cover, mainly to radiation losses; ii) improved mechanical stability of the granular silica aerogel layer. Thus, fewer compartments will be needed, and a more useful cover area will be achieved.

In this paper will be presented the steady state efficiency of the updated version of the FPC. The experimental results will be compared against a numerical model for design/prediction purposes (Zheng et al., 2024), to assess the overall results.

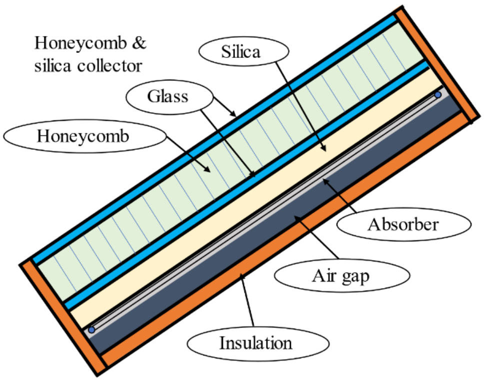


Fig. 1. Basic concept of the PV/T collector with transparent insulation

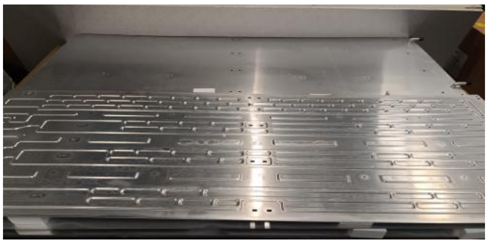


Fig. 2. Aluminium cold plates for the advanced thermal absorber

2. Methodology

To achieve an optimal design, a methodology based on a systematic use of experimentally validated numerical simulation tools will be used. The numerical simulation tools will be used in two levels: i) to optimize the thermohydraulic design of the high-performance absorber; ii) overall optimization of collector, mainly focused in the different TIM layers, i. e. plastic honeycomb and silica aerogel. A 1D multilayer semiempirical model will be used for design/prediction purposes. Fig. 3 shows details of the variables involved in the cover calculation. Otherwise, an already existent test rig (see Fig. 4) will be employed for experimental validation/assessment of the prototype.

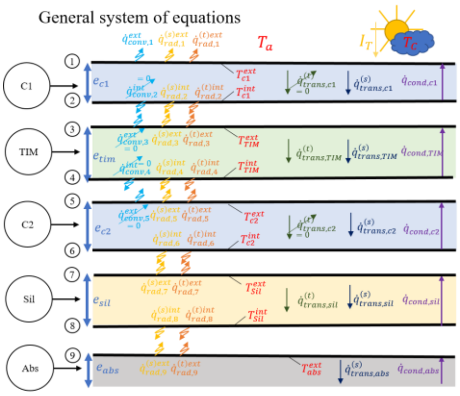


Fig 3. Representation of heat transfer and variables for each layer for the 1D multilayer model

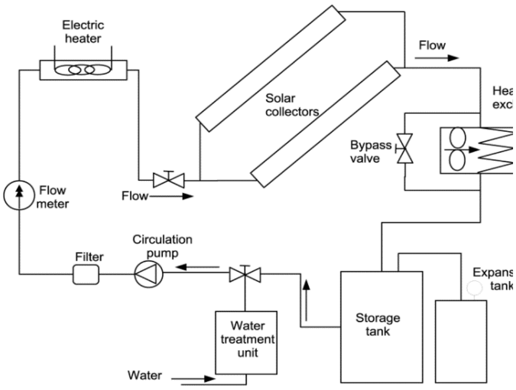
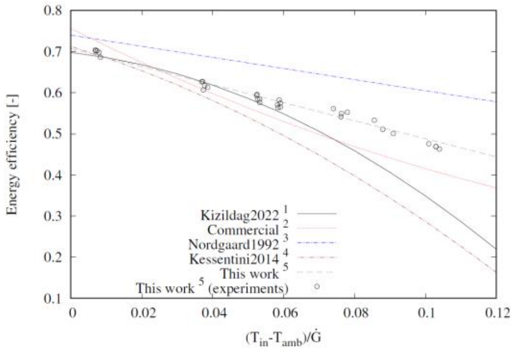


Fig 4. Test rig for the thermal experiments of solar collectors (CTTC)

3. Previous results

A previous version of the FPC was developed (Zheng et al., 2024). Fig. 5 shows the results of the efficiency curve. As can be observed, the results are higher than those of conventional FPC collectors in the zone of the efficiency curve, corresponding to high working temperatures/low radiation. It is expected to improve this result, as the overall heat transfer coefficient for the improved absorber is expected to achieve values higher than 250WºC-1m-2, with enhanced construction, i.e., compactness of the granular silica aerogel layer.

Fig. 6 shows the prototype in the previous version. As can be observed, different insulated bars were introduced in the cover to prevent the movement of the silica aerogel layer. This movement originated from the lack of stiffness of the absorber, making it very difficult to achieve complete compactness of the silica aerogel layer, estimated at 85%. Moreover, the insulation bars produced an optical loss of about 10-15%. These values are expected to improve in the new prototype version.



Fig, 5. Efficiency curves obtained experimentally and numerically 1D numerical tool (Zeng et al., 2024)

Fig, 6. Efficiency curves obtained experimentally and numerically 1D numerical tool (Zeng et al., 2024)

4. References

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