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Performance Amelioration of Flat Plate Solar Collector with Simple and Efficient Techniques

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ABSTRACT – A numerical study of solar flat plate collector using FLUENT software is performed. To enhance the performance of the solar collector we studied the effect of selective coating on absorber, then the thickness of air gap. Indeed; absorber with selective coating enhances the effective efficiency from 0.35 for a nonselective absorber to 0.51 for a selective absorber. Second, when decreasing the air gap thickness until an optimum distance; the effective efficiency increases and the thermal losses decrease. This study highlights that the optimal configuration for solar collector should be with a selective absorber, and an air gap thickness of 17mm.

Keywords: solar flat plate collector; air gap; effective efficiency

I. INTRODUCTION

Flat plate solar collector is very useful in many sectors, such as the textile industry, agriculture, desalination and space heating, and it is simple in manufacturing. For these reasons the improvement of its performance remains an important subject for researchers and scientists. The main problem of the flat plate solar collector is manifested in thermal losses through the front of the collector. Heat losses are mainly caused by radiative and convective exchanges. A high efficiency of the collector can be achieved when heat losses are reduced. To achieve this aim; we studied the effect of selective coating on absorber sheet, then the distance between the transparent cover and the absorber plate.

According to Fatima et al [1], collector performance is very sensitive to air gap thickness, they show that a small thickness reduction of about 3mm leads to an increase in efficiency of around 150%. But the collector structure does not allow them to reduce the thickness below 17mm. so they couldn't determine the optimal value of distance between absorber and transparent cover

II. METHODOLOGY:

The modeling of the solution domain, the grid generation, the boundary conditions, the simulation procedures and techniques used in this work are described in this section.

Our numerical investigation is based on a 3D model of a flat plate solar collector. In order to validate our numerical model, a first model interprets the geometry of the solar collector experimentally studied by N.Moummi [2].

Gambit 2.3.16 is used for geometry creation and meshing. The generated mesh consists of 1083381 nodes.

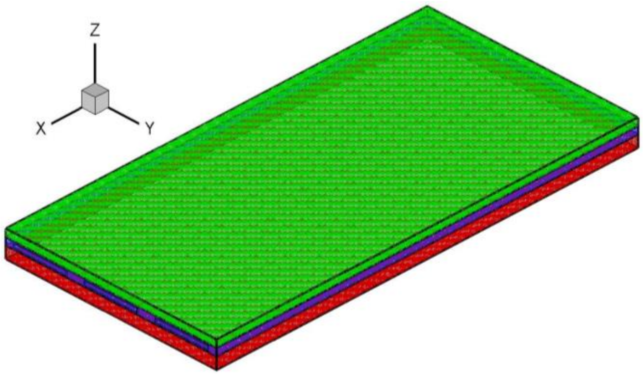

Figure 1: Mesh of the solar collector with Gambit 2.3.16

The assumptions considered in our calculation domain are listed below:

- The fluid is incompressible air
- Climatic condition corresponding to fair weather conditions.
- The inlet air with ambient pressure

Thermal properties or air is considered constant. Except for the density change with temperature, described by the Boussinesq approximation.

Boundary conditions for simulation are explained in this section:

1) At the inlet: the condition "velocity inlet" is imposed for the air, the velocity is calculated from the volume flow rate, and the air temperature is 299.14 K at the inlet.
2) The top plate considered as wall, is a

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"semi-transparent" cover with a "mixed convection" condition.

3) The absorber plate considered as wall, with a 0.0004 m of thickness, a "coupled" condition is applied.
4) Bottom and lateral plates with a "non adiabatic" condition assumed to be good isolations.

In this simulation, the fluid flow is studied under steady state and unsteady turbulent flow conditions. The K-ε turbulence model is enabled. The radiation problem is resolved using the discrete ordinate (DO) radiation model. SIMPLE algorithm is chosen as scheme to couple pressure and velocity. First-order up wind scheme was chosen for energy and momentum equation.

III. RRESULTS AND DISCUSSION:

a. Validation of the CFD model

Our numerical results are compared with the values of experimental results of N.Moummi [2] under a constant solar heat flux 900 w/m². Results of numerical simulations and experimental results of N.Moummi [2] are plotted in Fig.A.2; showing a satisfactory agreement between numerical and experimental results.

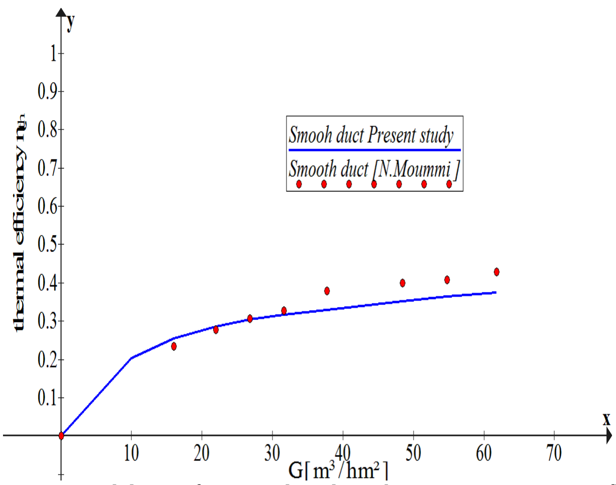

Figure 2: Validation of numerical results with experiments at constant flux of 900w/m².

b. Influence of selectivity of the absorber*:*

The purpose of this section is to demonstrate how to increase the efficiency of the solar collector by minimizing the heat losses by radiation, thus by optimizing the optical properties of the absorber. Two types of absorber sheets are tested; nonselective and selective, and their effective efficiencies are compared.

Results show a major enhancement in solar collector performance due to the selective coating, this is explained by the suppression of thermal losses by radiation transfer.

To conclude, in this section we have shown that the selective absorber is always more efficient than nonselective absorber for any volume flow rate and any solar radiation.

c. Influence of air gap thickness:

In this section we consider the absorber plate for all solar collector simulated as a selective absorber ($\varepsilon=0.1$, $\alpha=0.95$)

The air gap height of the reference collector (R) is e=25mm. At first, we minimize the air gap thickness and we consider (R-8mm) and (R-9mm).

Numerical results obtained prove that the optimal distance between the absorber and the transparent cover is 17mm (R-8mm), for any volume flow rate and any solar radiation.

IV. Conclusions:

From numerical studies in a flat plate solar collector, it is found that a selective coating on an absorber sheet enhance the collector efficiency in a remarkable way.

The second way to reduce thermal losses is to suppress or at least to minimize natural convection in the air gap between absorber plate and transparent cover. We have found that the optimal thickness of air gap is 17mm, which improves the collector performance. A slight decrease in air gap thickness ~8mm leads to a considerable improvement in efficiency. This result is very valuable and will be provided to the manufacturer.

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