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STUDY OF SOLAR AIR HEATER ENERGY AND EFFICIENCY USING COMPUTATIONAL FLUID DYNAMICS

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Abstract: *Solar energy radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar air heater is a type of energy collector in which energy from the sun is captured by an absorbing medium and used to heat air. Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. The comprehensive details of the flow field which are obtained using CFD code will help in understanding the fin behavior under different cases and thereby suggest possible modification of solar air heater.*

Keywords: *Fluent, Solar air heater, Gambit, CFD, Solar Energy, Fins.*

I. INTRODUCTION

In a solar air heater, the fins located in flow area increases the heat transfer coefficient and output temperature of air. Accordingly, collector efficiency increases too. However, an increase is observed in heat transfer. Forson, F.K., Nazha et al [2] provided a design tool, capable of predicting incident solar radiation, heat transfer coefficients, mean air flow rates, mean air temperature and relative humidity at the exit.

II. LITERATURE REVIEW

Kurtabas et al. (2006) Investigate solar air heater with free and fixed fins for efficiency and exergy loss and describe each of the fins, which are in the form of rectangular having two different surface areas, is located on the absorber surface in free and fixed manners. In the first case, the fins are located on the absorber surface in a way to be able to freely move. In the second case, it has been fixed to the absorber surface. The absorber surface area (A) is 1.64 m2. The fixed and free fins with 8 and 32 items whose surface areas (Af) are 0.048 and 0.012 m2 are located on the absorber surface.

Chaube et. Al. (2006) [7], Analyze the heat transfer augmentation and flow characteristics due to rib roughness over absorber plate of a solar air heater. And discuss a computational analysis of heat transfer augmentation and flow characteristics due to artificial roughness in the form of ribs on a broad, heated wall of a rectangular duct for turbulent flow (Reynolds number range 3000-20,000, which is relevant in solar air heater) has been carried out.

Deniz et. Al. (2010) [13], Experimental investigation of three different solar air heaters: Energy and exergy analyses. Their aim to study and compare three different types of designed flat-plate solar air heaters, two having fins (Type II and Type III) and the other without fins (Type I), one of the heater with a fin had single glass cover (Type III) and the others had double glass covers (Type I and Type II). The energy and exergy output rates of the solar air heaters were evaluated for various air flow rates (25, 50 and 100 m3/m2 h), tilt angle (0_, 15_ and 30_) and temperature conditions versus time. Based on the energy and exergy output rates, heater with double glass covers and fins (Type II) is more effective and the difference between the input and output air temperature is higher than of the others. Besides, it is found that the circulation time of air inside the heater played a role more important than of the number of transparent sheet. Lower air flow rates should be preferred in the applications of which temperature differences is more important.

Marc et al. (2011) [19], Performance of a photovoltaic/thermal solar air heater: Effect of vertical fins on a double pass system. They found that the steady state effect of vertical fins is assessed on a photovoltaic/thermal solar air heater having a double pass configuration in which fins are placed in the lower channel perpendicular to the direction of air flow. Air passes through the upper channel of the air heater and before passing in the opposite direction through the lower channel. The effects of design, climatic and operating parameters are evaluated on temperatures, efficiencies and other parameters. For fixed operating conditions, fins are observed to increase heat transfer area and rate, reduce cell temperature about 16°C, and improve thermal and electrical efficiencies. Higher packing factors are advantageous as they increase electrical output per collector area and reduce cell temperature.

Ashish et. Al. (2012) [17], designed CFD based fluid flow and heat transfer analysis of a v shaped roughened surface solar air heater. They conducted Computational Fluid Dynamics (CFD) study to investigate the heat transfer and friction loss characteristics in a solar air heater having attachments of V-shaped ribs roughness at 600 relative to flow direction pointing downstream on underside of the absorber plate. The computations based on the finite volume method with the SIMPLE algorithm have been conducted for the air flow in terms of Reynolds numbers ranging from 5000-15000. The parameter investigated is the relative roughness height (e/DH) ranges from 0.0216-0.043 and relative roughness pitch (p/e) ranges from 6-12.

Ho ming et. Al. (1996) [5], purposed a method for efficiency improvement of flat-plate solar air heaters and said that The barriers were placed with uniform spacing and in parallel, thereby dividing the air channel (collector) into parallel subchannels (subcollectors) of the same size. These subcollectors were connected in series so that air flowed through them in sequentially reversed directions. Experimental studies were performed for different locations of the barriers.

III. MEASUREMENTS AFFECTING FACTOR

The following factors can affect the analytical result of solar air heater using computational fluid dynamics, during the time of computation.

3.1 Angle:

The latitude angles are affect the temperature and efficiency of solar air heater. If the angle lying between the latitudes of 24 and 33 degrees, it receives significant amount of sunshine during summer and winter. This favorable geographical position places it among the countries which are endowed with enormous potential for solar energy utilization.

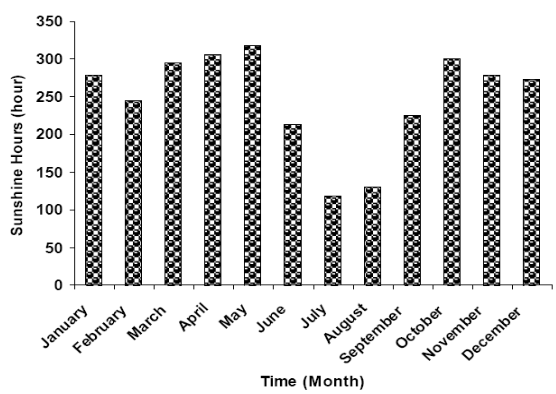

Figure 3.1: *Monthly mean sunshine hours*

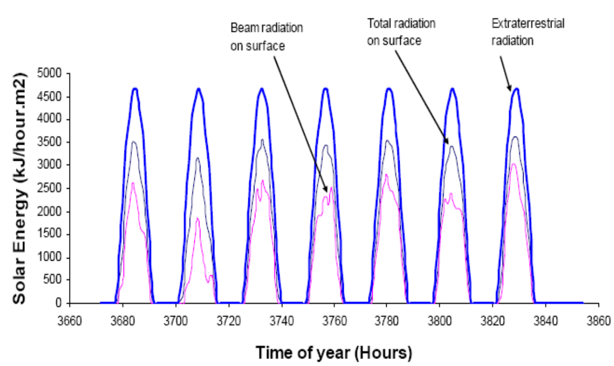

Figure 3.2: *Extraterrestrial, total and beam solar radiation for the first week of June*

3.2 Glazing Materials:

The function of the glazing is to permit maximum possible short wave solar radiation and minimize the leakage of long wave thermal radiation from the absorber collector. The glazing should be transparent having a high transmittance for incident short wave solar radiation and low transmittance for thermal long wave radiation emitted by collector.
For longest life and maintained transmittance, the most appropriate glazing material is tempered plate glass. It has above 90 percent transmittance for short wave solar and very low transmittance for long wave thermal radiation emitted by the absorber.

3.3 Insulation:

Solar collector must be insulated from all sides to minimize the heat losses and increase thermal efficiency. Different materials are used for insulation, best one are those which have low thermal conductivity low density, long life and low cost. An otherwise well-designed solar collector will experience excessively high stagnation temperatures that will cause polymer based insulations like polyurethane and polystyrene to outgas and rapidly destroy the effectiveness of the collector.
Urethane and closely related products may be prohibited in collectors in fire hazard areas, due to their ability to produce toxic fume at high temperature. When these materials are used in solar collectors, they should be used underneath a substantial blanket of other insulation material, such as binder-free fiberglass to reduce the hazard of exposure to high temperatures, and should have an intervening tight vapor barrier.

3.4 Fins:

Fin material has a high thermal conductivity. The fin is exposed to a flowing fluid, which cools or heats it, with the high thermal conductivity allowing increased heat being conducted from the wall through the fin. The design of cooling fins is encountered in many situations and we thus examine heat transfer in a fin as a way of defining some criteria for design.

Convection: Heat transfer between a solid surface and a moving fluid is governed by the Newton's cooling law: $q = hA(Ts-T\infty)$. Therefore, to increase the convective heat transfer, one can

a. Increase the temperature difference ($Ts-T\infty$) between the surface and the fluid.
b. Increase the convection coefficient h.
c. Increase the contact surface area A.

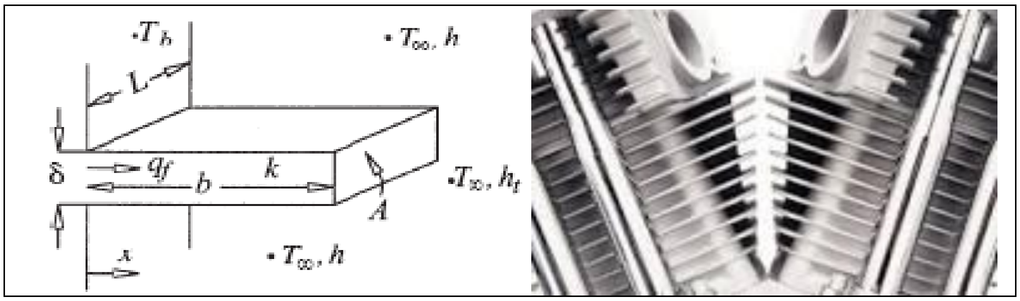

Figure 3.3: *Structure of fins*

IV. CFD PROCEDURE

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved.

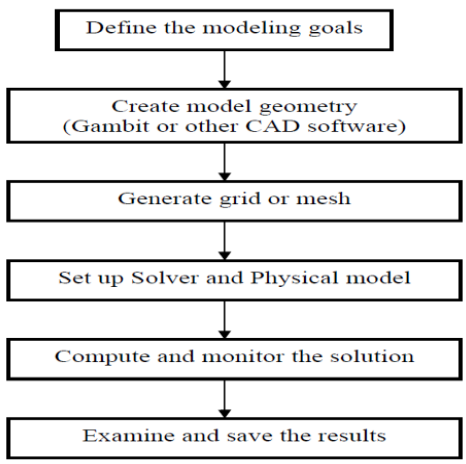

Figure 4.1: *Steps involved in the CFD analysis procedure*

V. CONCLUSION

Fins located on the absorber increase heat transfer and pressure drop. Fin also increases both outlet temperature of air and pressure drop. That is the most probably the fin to work as a fin conducted heat from the absorber and also to prevent the developing of the boundary layer. However, without fin works only as a resistance changed flow lines because of not joined on the absorber. Therefore, pressure drop decreases changing fin location.

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