A Review on Thermal Performance of Solar Water Heater Using Porous Medium and Agitator

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Abstract- **Energy application from sun to heat water is well known. Solar water heater is device which is used for heating the water for domestic and industrial purposes by utilizing the solar energy. In this review paper effect of porous material on the performance of solar water heater have been carried out. porous medium i .e metal foam, geometry of absorber plate and collector, other various things that have been investigate for performance improvement of the solar collector. Agitator is used in solar collector. The basic function of agitator in the riser tube is to increasing heat transfer; packing of collector surface with pebbles and metal chips is for longer heat absorption and enhanced heat capture respectively. It has been found that the efficiency of the solar collector with porous medium is more among all other combinations. An ASHRAE standard is used to examine the effects of metal chips on the solar collector performance at different flow rates.**

Index Terms **Flat plate solar collector, Porous media, Thermal performance, Pressure drop.**

I. INTRODUCTION

Heat transfer phenomena are applied in many industrial devices such as heat exchanges in petroleum engineering, filtration, geomechanics, and solar energy. In this paper using a solar energy for hot water generation is one of the engineering major interest areas that are concerned with sustainable energy.

Flat plate collector using porous medium and agitator is the most innovative method to improve thermal performance of solar water heater at the cost of low. The easiest and the most effective ways to utilize solar energy are to convert it into thermal energy for heating applications by using solar collectors. In solar water heater, solar collectors are a main part of solar heating system, which absorb the solar radiation and transfer it to moving fluid. We know that, there are three types of collectors and many forms of storage units. The three types of collectors are flat-plate collectors, focusing collectors, and passive collectors from these three types of collector Flat plate collector are used in this project. Flat Plate Solar Collector (FPSC) is the oldest and the most widespread one. These kinds of collectors essentially have low efficiency and have been used for several decades without any significant attempts for improving their performance and changing their design.

Improvement of the solar flat plate collector thermal performance can lead to decreasing of its size and fabrication cost. The working fluid and the collector plate are two major components of a FPSC. In this work, using nanofluids as a working fluid is an effective method which can improve the collector thermal operation.

In order to continue and extend previous studies, this paper present Heat transfer in porous media has been used for heat transfer enhancement in solar water heater because of its considerable advantages of high solid thermal conductivity and large specific area. Porous medium i.e. metal foam can improve the collector thermal performance due to their significant effect on the base fluid thermal conductivity and also their possible effect on the thermal boundary layer. There are a great attempt to investigate the effect of different sorts of nanoparticles on the thermal performance of FPSC.

A. *Solar Flat plate collectors:*

Flat-plate collectors are the most common collectors for water heating (liquid type) and for space heating installations (air types). In simple words a flat-plate collector is an insulated metal box with either glass or plastic cover, which is called glazing as shown in Fig.3. It is very easy to explain the working phenomenon of flat-plate collector. The sunlight passes through the glass coating and strikes the absorber plate. The absorber plate then starts to heat concentrating solar radiation into heat energy. The heat is then transferred to liquid passing through the flow tubes.

Most solar collectors are boxes, frames that contain these parts:

(1) Clear covers that let in solar energy;
(2) Dark surfaces inside, called absorber plates, that absorbed heat;
(3) Insulation materials to prevent heat from escaping; and
(4) Vents or pipes that carry the heated air or liquid from inside the collector to where it can be used.

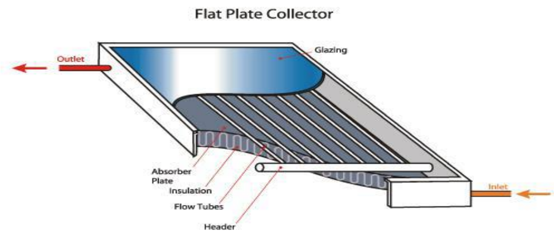

Figure 3: Solar flat plate collector

B. Flat plate collector filled with porous media

Porous medium is the main material of this project. In this paper porous medium is a small tiny chips .with the help of small tiny chips of metal heat transfer coefficient increases. A porous medium (or a porous material) is a material containing pores (voids). The skeletal portion of the material is often called the "matrix". The pores are typically filled with a fluid (liquid or gas). The concept of porous media is used in many areas of applied science geophysics), biology and biophysics, material science, etc.

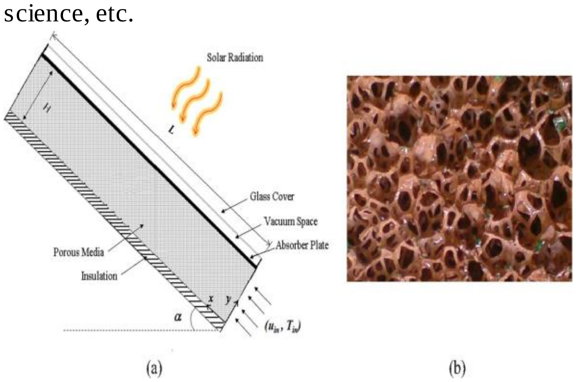

Figure:2 Flat collectors filled with porous medium

II. THERMAL PERFORMANCE ANALYSIS

By measuring the values of inlet and outlet temperatures, total rate of useful output energy from the working fluid area can be determined as follows:

$$Q_u = mC_p\left(T_{f,o} - T_{f,i}\right) \quad (1)$$

Where Q_u is the useful gain of energy, and C_p is the heat capacity of water. Similar to a conventional collector, the useful heat gain of the working fluid in the collector with porous media can be expressed in terms of the absorbed energy and the lost energy from the absorber plate:

$$Q_u = A_c F_R\left[I(\tau\alpha)_e - U_L\left(T_{f,i} - T_a\right)\right] \quad (2)$$

where I is incident solar radiation on the collector per unit area, (□$\alpha)_e$ is the effective transmission-absorption coefficient, F_R is the collector heat removal factor, and U_L is heat loss coefficient. Also $T_{f,i}$ *and* $T_{f,o}$ are the fluid inlet and outlet temperatures, respectively and T_a *is* the ambient temperature

$$\eta = F_R\,(\tau\alpha_e) - F_R U_L\,\frac{(T_{f,i} - T_a)}{I} \quad (3)$$

Collector efficiency is a measure of its performance and is defined as the ratio of the collected useful heat gain to the solar energy incident on the collector plane.

$$\eta = \frac{Q_U}{LA_C} = \frac{mcp\,(T_{f,o} - T_{f,i})}{LA_C} \quad (4)$$

The convection heat transfer coefficient can be written as

$$h = \frac{Q_u}{A_p \Delta T_m} \quad (5)$$

Where A_p is the heat transfer surface, and ΔT_m is the temperature difference between the wall and the bulk temperature of the working fluid.

ΔT is calculated by measuring a mean temperature between the inlet and outlet flow in the porous channel, as Follows:

$$\Delta T_m = T_w - \left(\frac{T_{f,i} + T_{f,o}}{2}\right) \quad (6)$$

The Nusselt number based on the hydraulic diameter is given by,

$$N_u = \frac{hD_h}{k_f} \;\ldots\ldots.. \quad (7)$$

in which D_h is hydraulic diameter of the flow channel cross section and K_f is thermal conductivity of the working fluid. Also, in the present study the Reynolds number is defined as:

$$R_{eD_h} = \frac{\rho_f U D_h}{\mu_f}\ldots\ldots.. \quad (8)$$

Where U is the fluid mean velocity at the porous channel entrance, f is the fluid density and f is the fluid viscosity.

III. LITERATURE REVIEW

1] H.Javaniyan, jouybari, S.Saedodin [1] conducted studies on Experimental investigation of thermal performance and entropy generation of a flat solar collector filled with porous media. In their studies, thermal performance of flat plat collector fully filled with porous channel has been performed based on ASHARE standard. Using porous channel enhances the optical efficiency and reduces the heat losses in lower values of Reynolds number due to improving the potential of solar energy absorption by working fluid. Nusselt number has a greater value in porous channel collector and its value enhances relatively up to 82% using porous media.

S. Saedodin, S.A.H. Zamzamianb, M. Eshagh Nimvaric, S.Wongwisesd,e, H.Javaniyan Jouybari[2]conducted studies on Experimental and numerical analysis of Performance evaluation of a flat-plate solar collector filled with porous metal foam. In these studies, the effect metal foam of fully filled porous channel flat plate solar collector have been investigated experimentally and numerically. these papers gives the information about the thickness of porous channel has been optimized based on absorber wall and insulated wall, The nusslet number improves relatively up to 82% with using porous material .porous material improves the absorbed energy parameter up to maximum 18.5%.Sorour, [3] has designed and fabricated three models for FPSC in which the working fluids obtains the thermal energy from a transparent cover and flow perpendicular to a porous absorber. Lansing and Clark [4] in their studies an analytical solution to determine the temperature distribution. It is used in solar air collector they improve performance of collector by 102%.Al-Nimr and alkam, improve thermal performance of tubeless FPSC by placing porous medium layers at the boundary side of the collector and also the effect of porous are used at boundary wall of tubular FPSC. Leinstreuer and chaing[5]have numerically solved coupled fluid and heat transfer porous medium FPSC and compared its thermal performance with that of a tubular collector. Mbaye and Bilgen,[6]a numerical study of natural convection in porous wall solar system. They investigate effect of different geometrical factors. H.P. Garg et al. [7] reported that the storage potential of built-in-storage type solar water heater with transparent insulation is higher than that of a system with moveable insulation. R.P. Sharma [8] proposed that Agitator in the raiser tubes enhanced heat transfer while Pebbles and stainless steel chips enhanced the retention period of heat. The internal dimensions of the collector were 1.2m x 0.6m x 0.18m. Agitator using curling copper wire inside the raiser tubes in the form of a helix was used to increase the heat transfer coefficient. Pebbles and stainless steel chips were used to cover the absorber surface to enhance heat transfer and retention of the transparent insulation more than offsets its better insulating property during the sunshine hours. Raj Thundil Karuppa R et al. [9] tested with the absorber made of 2 sheets of GI (1 mm) with integrated canals, painted in a silica based black paint solar water heater and small pump for forced circulation. It can be concluded there is little difference between the output temperatures while using copper and GI different collectors. Efficiency of the flat plate collector for copper is 24.17% and GI is 20.19%. Alberto García, et al. [10] investigated the heat transfer augmentation in the flat plate solar water collector using wire inserts experiment were performed with different mass flow rate values. It was concluded that wire-coils can be inserted in the riser tubes of flat plate solar water collectors for improving its heat transfer rate and thermal efficiency. By inserting wire-coils the collector efficiency was increase by 14 -31%, counted on mass flow rate. Volker Weitbrecht *et al*., [11] performed, the results of an experimental study conducted in a water solar flat plate collector with laminar flow conditions to analyze the flow distribution through the collector. LDA measurements were carried out to determine the discharge in each riser, as well as pressure measurements to investigate the relation between junction losses and the local Reynolds number. Analytical calculations based on the measured relations are used in a sensitivity analysis to explain the various possible flow distributions in solar collectors.

IV. DISCUSSIONS

In response of various thermal performance of solar water heater Using porous medium have been investigated in recent years [1,2,3,4]. In this literatures different porous medium are used for the increasing thermal performance and thermal efficiency of solar collector and they gives the different efficiency of collector. Using nanomaterial's i.e. Porous medium in solar collector increasing thermal performance. In this paper review of natural convection in porous wall solar system study. Because they investigate effect of different geometrical factors. Using agitator in riser tubes enhanced heat transfer while pebbles and stainless steel chips enhanced retention period of heat[5,6,7,8]. In addition agitator with wire coils in riser tube increases the heat transfer rate and changing pebbles size as well as using copper metal material i.e. porous medium gives long heat retention period[10,11].

V. CONCLUSION

In this paper study of effects of porous metal foam on the thermal performance and pressure drop of a fully porous channel FPSC. Solar flat plate collector has low efficiency because of convention heat transfer loss so that in this paper this factor is considered and prevention of this loss is done by porous medium and agitator in riser tube.

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