SOLAR WINDOW FOR HOT DOMESTIC WATER AND PASSIVE DESIGN

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Abstract - In this study the effect of using water glazed window and nanofluid glazed window on the thermal comfort inside a room and on the potential of obtaining hot domestic water will be investigated. To achieve this study, three identical windows were constructed and used in these work, the first one is a standard one, which will be used as a reference one for comparison purposes. The second one is a glazed one with the cavity being filled with water and a heat exchanger is inserted within this cavity through which liquid water flows and acts as a load to cool down the solar heated water in the cavity. The third window is the same as the second one but with nano fluid being flowing inside the heat exchanger. Zinc Oxide was added to pure water to form a nanofluid (0,02%, 0.04%, 0.05%,0.06%) The three windows were installed side by side and experiments were conducted simultaneously. The temperatures of ambient, inside, water and nonfluid inlet and outlet were measured on hourly basis and stored in a data logger. Also the incident solar radiation was measure.
It was found that the efficiency reaches a maximum value of almost 7% that corresponds to the Nano particle concentration of 0.05%. This indicates that this concentration is the optimum one for most efficient domestic hot water production using solar window, and the inside temperature for the case of Nano fluid is the minimum one almost for all day.

I. INTRODUCTION

To reduce dependence on traditional energy sources threatened with extinction and to address environmental threats, increasing thermal emission rates, to climate change that is becoming increasingly dangerous one day after another. Global attention has grown to diversify and renew energy sources, especially renewable sources to reduce using fossil fuel. Solar energy represents one of the best solution for this purpose where it is available without the need for transportation and distribution. There are many ways to take advantage of the vast energy reserves that are inexhaustible and must be exploited where appropriate conditions and elements are available.
Solar window is one of the forms of exploitation of solar energy as an important part of buildings, and it represents the bulk of facade to the majority of commercial buildings. The main using of this technology is in residential buildings where the demand for hot water has a large impact on energy bills. Solar Window are commonly used to heat water for residential buildings but can also be applied to large scale water pre-heating like swimming pools in gym centers or hotels without need for more available roof space. In addition Solar window twchnology may be used to control the heat exchange between the inside of the buildings and the ambient, this will help ini achieving thermal comfort inside buildings both in Winter and Summer.
Gonzalo, et.al (October 2017) described system to maintain a small glazed pavilion located in Sofia (Bulgaria) at the desired interior temperature over a whole year. The system comprises i) the use of Water Flow Glazing facades (WFG) and Radiant Interior Walls (RIW), ii) the use of free cooling devices along with traditional heat pump connected to pv panels and iii) the use of a new Energy Management System that collects data and acts accordingly by controlling all components. The effect of these strategies and the use of active systems, like Water Flow Glazing, are analyzed by means of simulating the prototype over one year. Summer and Winter energy management strategies are discussed in order to change the SHGC value of the Water Flow Glazing and thus, reduce the required energy to maintain comfort conditions.
Gonzalo and Ramos (2016) presented the emerging concept of “dynamic window” which is more as a multifunctional envelope that produces and manages energy rather than simply a static piece of coated glass. These facade systems include switchable windows and shading systems. The aim stated in their work is to study the behavior of water flow glazing in regards to the solar heat gain coefficient. Heat absorption can be controlled in water flow glazing to adapt the envelope to different climate conditions and façade orientations. The results of this study show that the solution of double glazing with a circulating water chamber is a less polluting and more efficient option than the systems currently used.
Lojkovics and Kosicanova (2013) presented a novel system of glazing with water flow in cavity within its one-year performance. They found out that the indoor room heat gain can be reduced and this system could be used as a pre-heated water source.

Chow, et, al., (2011) made a comparative study with the use of different glazing types in a water-flow window that was constructed at the front wall of an environmentally controlled test cell to monitor its performance under full-scale real-building-like condition. Through this, cold feed water circuit removed the absorbed heat away from the buoyant water circulation in the window circuit. The heat removal allowed a reduction of energy consumption

in air-conditioning and services hot water systems. Year round energy performance was then predicted by numerical models, which were successfully validated by the experimental data. The economical payback periods of the different glazing combinations are found less than 5 years under the Hong Kong subtropical climate.

Chow and Li (2013) introduced a design of water-filled double reflective glazing system and the prediction of its annual performance through computer simulation with the use of Hong Kong TMY weather data is presented. The monthly indoor heat gains through the window are compared with conventional single/double reflective glazing. The results show that the indoor room heat gain can be significantly reduced by utilizing this novel glazing system. The absorbed heat by water flow in cavity can be used as a pre-heated water source to serve the hot water system.

Chow, et.al (2011) presented a comparative study reports for conventional single and double pane absorptive glazing with the integrative thermal performance of a water-flow absorbing window. It was found out that water passage in this way can effectively lower the glass pane temperature, reduce room heat gain and therefore, the air-conditioning electricity consumption. Thermal comfort can be enhanced.

Bahaj et.al (2008), exploreed technical, economic, environmental and indoor comfort implications of emerging glazing technologies for energy control of highly glazed buildings in arid Middle Eastern climates,. The work included predictions through thermal simulation of the impact of electrochromic glazing, holographic optical elements (HOE), aerogel glazing and thin film photovoltaics on two example buildings. Potential reductions in cooling demand are assessed.

Ismail .et.al., (2008), Compared between the thermal efficiency of two glass windows one filled with an absorbing gas and the other with a PCM and exposed to solar radiation in a hot climate is done. To model double glass window filled with infrared absorbing gases, a CW real gas model is used. A radiative convective conductive model and a radiative conductive model were investigated. Three mixtures of gases were used; a strongly absorbing gas mixture, an intermediate absorbing gas mixture and a transparent to infrared radiation mixture. To model the double glass window filled with a PCM, a relatively simple and effective radiation conduction one dimensional formulation is used. Heat transfer through the window is calculated and the total heat gain coefficients are compared and discussed.

Fifteen different glazing systems ranging from 3mm single glazed clear glass to double glazed with low-eand solar control coating, have been analyzed in terms of their human thermal comfort impact by Singh et.al.(2008). Thermal comfort was measured in term of PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied It is found that for cold station (e.g. Leh) all glazings except solar control glazings, ensure thermal comfort and total PPD is less than 10% (|PMV|p .(0.5For warm and hot climates, solar control glazings are thermally suitable. Results for winter night of Delhi shows that all the 15 glazings are inadequate for thermal comfort and PPD, due to cold feeling, varies between 27% and 33% approximately.

This experimental study was conducted on solar windows system, which consists of three side-by-side solar windows the first one will be used as a base window for comparison purposes. The second one will be with heat exchange installed within the layer that contains liquid water. The third one contains nanoparticles within the fluid that flows within heat exchanger. The main objective of the present work is to investigate the effect of nanofluid on the performance of a solar window.

II. EXPERIMENTAL SETUP AND PROCEDURE

As indicated figure 1, the experimental setup consists of three identical windows, each one has an area of 0.25 (0.5m*0.5m) and 6cm thickness. These windows were mounted vertical facing true south with an angle of 90 degrees. Each window has been designed carefully with triple glass, the distance between each plate of glass is 3cm (6cm window's thickness). The first one has been used as a base window for comparison purposes. The second and third windows have been installed with heat exchange between the layer that contains liquid water that faced to solar radiation whilst the other cavity, which is closest with inter room, has been filled with air. The third one is exactly like the second, but it contains the nanoparticles within the fluid that flows inside the copper tubes which works as a heat exchanger. They are all facing south at angle 90 degree. Each one is covered by polystyrene board from all sides except that facing south side

Also shown in figure 1, a storage tank filled up with water, which is heated up as the hot water emerging from the window flows within the heat exchanger that is immersed in the storage tank. The heated up water may be used for domestic purposes.

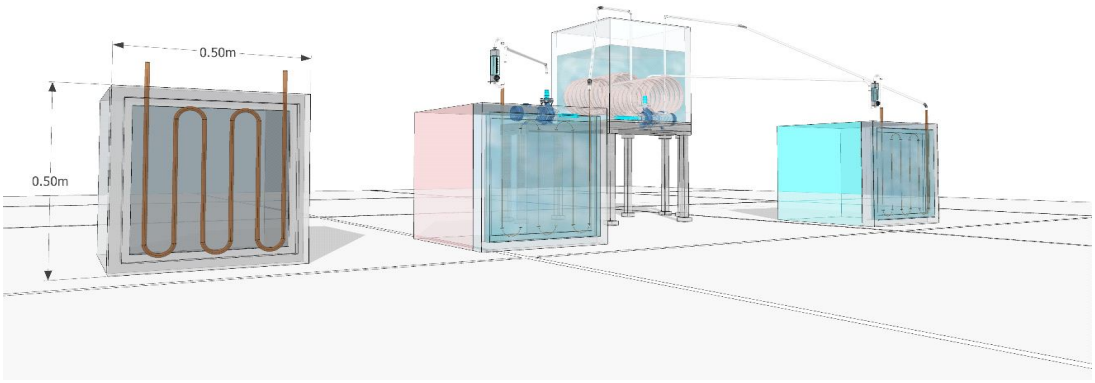


Figure 1. X-Ray shot of the system

After the achievement of a smooth flow of fluid within the windows, the flow rate of the fluid within the heat exchanger is measured using a calibrated flow meter. In this study, the flow rate of fluids in each window was fixed at 200 mml/min.

The next step was adding nanoparticles of Zinc Oxide (ZnO) to the flowing water in the pipes passing through the third window, four different mixtures are used in this work with nano particles concentration of 0.02%, 0.04%, 0.05 and 0.06%.

While maintaining a constant flow rate at 200 mml/min, the system is put into in operation and hence the water and nanofluid are forced to flow inside the heat exchangers using the electrical pumps.

For each value of nanoparticles concentration and for the constant flow rate of nanofluid and pure water within the heat exchangers, the hourly inlet and outlet temperatures of fluids entering and leaving each window were measured and stored using data acquisition system (DAS). In addition, the metrological data were obtained from a nearby a weather station and also stored in the DAS

III. RESULTS AND DISCUSSION

Figure 2, shows the hourly fluids temperatures increase as they flow through the heat exchanger inside the windows, with the nanoparticles concentration of 0.02 %. As indicated the outlet temperature exceed that of the input for bothfluids. This increase is expected due to the fact that both fluids absorb portion of incident solar radiation. However, the increase in the nanofluid temperature significantly exceeds that of pure water. This is due to the fact that the addition of nano particles will cause an increase in the thermal conductivity of water and hence more solar energy being absorbed leading to higher temperature. It is to be noted that as the fluid temperature increases, higher temperature of domestic hot water temperature may be obtained.

Finlay, it is to be noted that this increase in fluid temperatures is rather small, this is because the solar windows used are of small cross sectional area and due to the fact that both windows are installed in a vertical position to represent an actual case of windows in the walls of a building. These two factors cause a decrease in the solar energy being absorbed and hence lower values of temperature increase in the fluids passing through the heat exchanger.

Figure 2 .The different temperatures and the daily hours with ZnO concentration = 0.02

Similarly, figures 3 through 5 show the increase in both fluids temperatures as they flow through the soalr windows.. The nano particles concentration used in these three figures are 0.04, 0.05 and 0.06%.respectively.

As stated above, the increase in the nanofluid temperature exceeds that of the pure water and this is due to the increase in the thermal conductivity of the nanofluid, which is caused by the addition of the nano particles. This is evident in the two figures and for all concentrations of nano particles.

It may be noted from these figures and as well figure 2, that the increase in the nanofluid temperature was achieved when the nanoparticle concentration was 0.05%. This indicates that this concentration is the optimum one for most efficient domestic hot water production using solar window. Furthermore, the increase in the pure water temperatures increases to maximum values during the early hours before noon, then drops down and starts to fluctuate about a mean value. This behavior was noticed as well for the nanofluid. The drop and the fluctuations may be attributed to cloudy periods during the day.

Figure 3 The different temperatures and the daily hours with ZnO concentration = 0.04

Figure 4 The different temperatures and the daily hours with ZnO concentration = 0.05

Figure 5. The different temperatures and the daily hours with ZnO concentration = 0.06

The average daily efficiency of the solar window was calculated and presented in figure 6. As indicated the efficiency reaches a maximum value of almost 7% that corresponds to the Nano particle concentration of 0.05%. This is expected, since it was found that the optimum concentration of nano particles is 0.05%

Fig.6 The different Average Daily Efficiency

As stated previously, it is expected that the presence of fluid within the solar window will absorb solar radiation and hence cut down the amount of solar radiation that is transmitted into the room, this leads to more comfortable conditions inside the room and hence less electrical energy consumed to power the air conditioning units in buildings. This reduction in room temperature caused by the presence of both pure water and nanofluids is presented in figure 7. This figure shows the hourly temperature inside a small box, of which the solar window represents one wall of it. As indicated, three values of inside hourly temperatures were recorded, the first one for the reference window without fluids, the second one corresponds to case of pure water, while the third one corresponds to the case of nanofluid, the inside temperature for the case of nanofluid is the minimum one almost for all day, flowed by that of water. Furthermore, the is a significant drop in inside temperature caused by the presence of either fluid. This drop in inside temperature is caused by the fact that there exist water absorption bands in the visible and Infrared of the solar spectrum and hence most of solar radiation within these bands are absorbed by the water. In addition to the absorption band of water, the presence of the nanoparticles absorbs extra amount of solar radiation and hence lower inside temperature is achieved when Nano particles is present in the fluid to form Nano fluid.

Figure 7. The different of inside rooms' temperatures

Conclusion

In this study the effect of using water glazed windows and nanofluid glazed window on the thermal comfort inside a room and on the potential of obtaining hot domestic water were investigated. From this study, the following may be concluded:

- In general, the water glazed window may be used for indoor thermal comfort and to obtain domestic hot water.
- The nanofluid glazed window has higher potential for indoor thermal comfort followed by the water glazed window. While the conventional window is the least in providing indoor thermal comfort.
- Similarly, the nanofluid glazed window has higher potential for providing solar hot water followed by the water glazed window.
- The optimum concentration of zinc oxide in the nanofluid was found to be 0.05%, with this concentration a maximum temperature of hot water was obtained. Further with this concentration the indoor temperature was minimum.

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