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Modeling and Fluent Analysis of Solar Heat for Solar Water Heater

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ABSTRACT:

This work studies the performance of heat pipe solar collector for water heating. Experimental results are validated using analysis modeling. heat pipes with distilled water as a working fluid were used for experimental tests. Both natural and forced convective heat pipe condensing mechanisms are studied and their results are compared with different materials and different dimensions using 2 velocities Using solar power as base power and fundamental heat principle is our motto. Solar plate is designed with different dimensions and a experiment is conducted with two velocities ie(1m/s and 0.5m/s) on copper and aluminum materials Convection is the basic principle which we deal with and calculating higher efficiency on different material on 2 meters length plate.

INTRODUCTION:

The demand for energy is increasing at a substantial rate as the economy of the populous developing countries is growing. Currently, this high energy demand mainly depends on fossil fuel resources. Apart from the difficulty of meeting the high energy demand, the issue of environment and sustainability has led to a critical concern on power generation and its utilization. Fossil fuels are sources of emissions and are unsustainable due to their dwindling reserves, price rise and resource not evenly distributed in the world. Geopolitical instability in resource areas is also a major concern. Following this, today's agenda is power production from renewable resources which are environmentally benign and sustainable. Renewable energy sources such as solar energy are the long term options to substitute conventional energy systems.

Substantial amount of heat energy is used for space heating and hot water production in household energy system depending on the geographical location. In the Sweden for instance, space heating and domestic hot water accounts approximately 60% of the residential energy use in 2009 (Swedish Energy Agency, 2010) while it accounts 19.2% of the household energy demand in US in 2001 (US Department of energy, 2005) and 81.1% of the household energy in Canada in 2002 (Aguilar et al., 2005). The use of renewable energy technologies for production of heat energy can play a significant role in reducing the demand of fossil fuels for heat energy production and reduce CO2 emission.

Solar water heaters are the most developed renewable energy technologies used in the world. For the past several years, conventional flat plate collectors have been well studied and developed. Their relatively low cost, lower maintenance and easy of construction have made these systems very competitive and are widely used all over the world specially for low temperature thermal systems. Conventional flat plate solar collectors use water pipes attached to the collecting where water circulates either naturally or forced inside the pipes and so transfers the heat collected by the plate to the storage tank. The following are some of the limitations of conventional flat plate solar collectors for water heating .

• Low heat transported by the fluid which leads to low thermal efficiency

• Pipe corrosion due to the use of water

• Freezing of water used in cold nights

• The night-cooling effect due to the transverse flow of cooled water

• The extra space required for natural circulation due to the position limitation required

• And the heavy total system weight A design improvement of conventional flat plate collectors increases the solar energy share for hot water production. Due to the low energy density and transient nature of solar energy, designing appropriate heat transport system is important in increasing the solar fraction for standalone or simulated hot water production systems.

Employing heat pipes for solar water heating application is at its young stage and extensive studies are required to integrate heat pipe in solar collector systems so as to improve the heat transport. Since the advent of heat pipes in 1960, their importance in solar application such as solar collectors for domestic water heating, space heating and cooling has received increasing attention As the demand of energy conservation increases, heat pipes become more and more attractive for an increasing number of various applications. Heat pips have low thermal resistance for heat transfer than any other metals have Most of the above limitations of conventional solar collectors can be overcome by using a compact heat pipe solar collector system. Very high thermal conductanc (phase change heat transfer), the ability to act as a thermal flux transformer and an isothermal surface of low thermal impedance are very important properties of heat pipe for solar system application.

Several studies have been reported on the use of heat pipe for solar water heating systems. Ismail and Abogderah presented both theoretical and experimental comparison of wicked heat pipe solar collector and compared with conventional forced solar collector. Methanol was used for heat pipe working fluid and the condenser was 15 degree more inclination than the collector for better condensate return. Heat pipe solar collector was found with high efficiency compared to the conventional solar collector. Theoretical and experimental studies on wickless heat pipe solar collectors for waterheating have been reported. These studies use cross flow condenser heat exchanger. Distilled water was used as working fluid in heat pipes. The performance of wickless heat pipe solar collector was found to be sensitive to cooling water inlet temperature, absorber plate material and thickness and condenser length. It was also possible to know the optimum cooling water mass flow rate for best efficiency of the system. The effect of condenser heat transfer on the performance of plate type heat pipe solar collector with cross flow condenser heat exchange was studied using CFD methods Due to non-uniform velocity pattern in the heat exchanger, a mixed of natural and forced convective heat transfer models was considered and found to have better match with experimental results. However, there is scarce of study on the effect of different types of heat pipe condensers on the system performance of heat pipe solar collectors. In this study, both forced and natural convective heat transfer in condenser heat exchanger are studied and their performance is compared for the first time. The performance of natural convective heat pipe condenser type is compared with conventional natural circulation solar water heating system.

2.WORKING PRINCIPLE OF HEAT PIPE

The components of a typical cylindrical wicked heat pipe are copper tube with end sealed, wick structure, and a small amount of working fluid in thermal equilibrium with its vapor. It has three main sections as shown in Figure 1: the evaporator, adiabatic and the condenser sections. In solar collectors, the evaporator is bonded with the absorber of the collector and the condenser section is inserted in to the heat exchanger. The heat picked by the evaporator sinks at the condenser section. Heat loss in the adiabatic section is mostly ignored for good insulation. The working fluid is maintained at lower pressure in the heat pipe. The working fluid evaporates at the evaporator section and creates a vapor pressure to flow to the condenser section to condense. The evaporation and condensation happens at saturated temperature. The wick develops a capillary pressure to pump condensed liquid from condenser to evaporator to complete the circulation. The pumping can also be done by gravitation in gravity assisted heat pipes which is also common in solar collectors.

3.Heat Pipe Theory and Design

In the design of heat pipe, the characteristic of the three main components: the working fluid, the wick and the container are of important to attain the required heat transport capacity.

In order the heat pipe to work, the pressure drop in the fluid flow has to be compensated by the pumping pressure in the wick by capillarity.

3.1. Heat Transfer Limits

The physical properties of the fluid used and the wick properties determine the design to achieve a working heat pipe with required heat flux. Capillary, sonic, entrainment, boiling, frozen start up, continuum vapor, vapor pressure and condenser effects are physical phenomena that limit heat pipe heat transfer. The heat transfer limit for heat pipe can be caused by any of the above phenomena depending on the construction of the heat pipe and the operating environment. The lowest limit of these phenomena is considered as a design limit. The main design limitations are discussed as follows. The circulation of working fluid between the end zones happens due to the presence of wick structure. This limitation is very common in low temperature heat pipes for instance in hot water production. The limitation occurs when the capillary pumping power is not enough to overcome the pressure drops. The evaporator dries out if heat transfer above this capillary limit is attempted. The maximum heat transfer (Q max) calculation is based on the hydrodynamic properties of the working fluid, wick and the orientation of heat pipe. (Where ρ, σ, μ are the density, capillarity and viscosity of the liquid fluid; K - permeability of the wick, Aw -wick area, θ-inclination of heat pipe from horizontal, re-effective radius of the heat pipe, g-gravitational acceleration, *l*- total length of the heat pipe, H- heat of evaporation of the working fluid, subscript *l*- liquid. Sonic Limit Heat pipe operation is accompanied with extraction and addition of mass in the evaporator and condenser. The vapor velocity increases along the evaporator and reaches maximum at the end of the evaporator. Since the vapor diameter is constant the heat pipe can act a nozzle at the end of the evaporator. Since the vapor velocity cannot be greater than the speed of sound, a sonic limit develops. Where is the vapor specific heat ratio, R_V- gas constant, and T_v- temperature v_γ- Entrainment limit This limitation happens when water droplets are transported by the fast moving vapor due the shear force between the vapor and liquid at the interphase. If the heat transfer is too high, the evaporator dries out and the heat pipe stops working. Therefore, the maximum heat transfer possible with this limit. Heat pipe wall temperature in the evaporator can become too high when the liquid in the wick starts to boil due to high radial heat flux. The vapor bubbles in the wick prevent the liquid for uniform wetting and a hot spot produces. This leads a dry out in the evaporator and limits the heat transfer. Where - evaporator length, - conductivity of the wick material, P0- working pressure, subscript i_v, and 0 are internal , vapor and external respectively.

3.2. Selection of Heat Pipes

Heat pipe are classified based on construction and operation. Two-phase closed thermosyphon wickless gravity assisted and capillary driven are the most common heat pipe types used in solar application. Gravity is the main mechanism in the thermosyphon type to return the condensate from the condenser which is located above the evaporator. The entrainment limit is more profound in gravity assisted than capillary driven due to the free liquid surface. The opposite of entrainment, flooding is also a problem in thermosyphon heat pipe. Filling ratio is also very important factor in thermosyphon than capillary driven heat pipe. Dry out occurs because of pool type and non-distributed working fluid. Gravity assisted wickless are difficult in solar collectors with high degree of inclination because of pooling which create non-uniform liquid distribution along the absorber length. This creates an increase wall temperature in some part of the heat pipe. In a capillary driven heat pipe, a wick placed circumferentially in the internal of the sealed container is used to pump the working fluid from the condenser to the evaporator. Appropriate amount of working fluid is put inside the container to saturate the wick. It has betterperformance in transferring heat with a small temperature drop and long distance. The capillary limit is the main heat transfer limit in capillary driven heat pipe. A combination of wicked and gravity assisted heat pipe gives a compromised performance specially for solar application where the evaporator is long compared to other sections and need a uniform wetting properties. A design of gravity assisted wicked heat pipe for solar application is presented in this work.

ALUMINUIM

Velocity	Temperature	Single plate	Double plate	Triple plate
1m/s	Inlet temperature	295	295	295
	Outlet temperature	295.43	295.97	309.71

COPPER

Velocity	Temperature	Single plate	Double plate	Triple plate
1 m/s	Inlet temperature	295	295	295
	Outlet temperature	297.70	306.57	309.91
0.5 m/s	Inlet temperature	295	295	295
	Outlet temperature	300.49	318.83	329.97

Conclusion:

The solar heater plates is design in catia v5 using different catia tools with different parameters and imported in analysis and through analysis is done using CFD fluid flow module analysis

Analysis has been done on different dimensions with different velocity's i.e (0.5 m/s,1 m/s) on copper and aluminum materials

The output results of both aluminum and copper have nearly equal output results but aluminum react with hot and cold water at extremely conduction and emit aluminum oxides which may damage the plate

We conclude that using triple plate has more advantages than single plate and double plate on both velocity conditions (0.5 m/s,1 m/s)

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