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Study of Heat Pipes in Solar Collectors Using Nano Fluids

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ABSTRACT

This paper describes about the performance of heat pipes in solar collectors. The solar energy is the most readily accessible source of energy. It does not belong to anybody and is therefore free. It is also most important of the non-conventional sources of energy because it is eco-friendly. Solar energy captured by solar collector and an evacuated solar collector is most efficient and convenient collector among various kind of solar collector. Heat pipes plays important role in all electronic devices and also in solar collectors. Because the prime role of heat pipe is to reduce the over heat of the devices or collectors. Heat pipe heat exchanger is a simple device which is used to transfer the heat from one location to another location using an evaporation-condensation cycle. The day to day applications of heat pipe heat exchanger are water heater, heat engines, air conditioning and much more. The working fluid of heat pipe heat exchanger is NANO FLUIDS. NANO fluids are the solid-liquid suspension created by the combination of small NANO particles with base liquid(water).The commonly used NANO fluids are Alumina(Al2O3),Copper oxide(Cu2O),Titanium oxide(TiO2) and Au/water. The recently discovered NANO fluid is Graphene oxide due to its high thermal conductivity. The NANO fluid plays a vital role in many of the thermal applications like heat exchanger, solar power generation and Automobile industries because of its higher efficiency less, friction less heat loss and more advantages.

Keywords: Solar Collector, Capillary Force, Heat Pipe, Nano Fluid

I. INTRODUCTION

There are many sources of energy like solar energy, thermal energy etc., Heat energy can be obtained by heating the fossil fuels. There are many sources to avail the fossil fuels but these sources of fossil fuels are limited, but the other main disadvantages of fossil fuels is burning of these fossils fuels like coal, gasoline, methane etc., It can cause the environmental pollution and these are the non-renewable sources of energy. In our heat collector the main source of energy used is solar energy which is the renewable energy. Radiant energy emitted by the sun. It is called solar energy.

Heat pipe is a closed heat transfer device that combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between two solid interfaces. It is used to transfer the large amount of heat through long distance with small temperature difference between the sources and sink. The heat pipe is a sealed tube. There are three sections involved in the heat pipe evaporator section, adiabatic section and Condenser section. Heat pipe is partially filled with working fluid.

Nano fluids are the working fluid used here. When the working fluid absorbs the heat from the heat pipe it undergoes evaporation which converts fluid to vapor. The vapor then travels along the heat pipe to cold interface and condenses back into the liquid phase-releasing the latent heat. The liquid then moves to hot inter face to gravity and cycle repeats.

II. METHODS AND MATERIAL

1. Principle of Heat Pipeses

The principle of heat pipe heat exchanger is Thermal conductivity and Phase transition. Thermal conductivity is defined as the property of the material

to conduct the heat. Thermal conductivity of the material depends upon the temperature. Phase transition is the term which represents the transformation of phases between Solid, Liquid and Gases.

2. Sections of Heat Pipe

The heat pipe has three sections the evaporator, the adiabatic, the condenser. When the evaporator section is exposed to a heat source, the liquid inside the heat pipe get vaporizes and the pressure in that section increases. The vapor flows fastly toward the condenser section of the heat pipe by the increased pressure. The vapor in the condenser section losses heat to the heat sink and the vapor converted back to liquid by the transfer of the latent heat of vaporization to the condenser. It is the middle section of the heat pipe, the adiabatic portion, has very small temperature difference. The section of heat pipe as shown in figure: 1

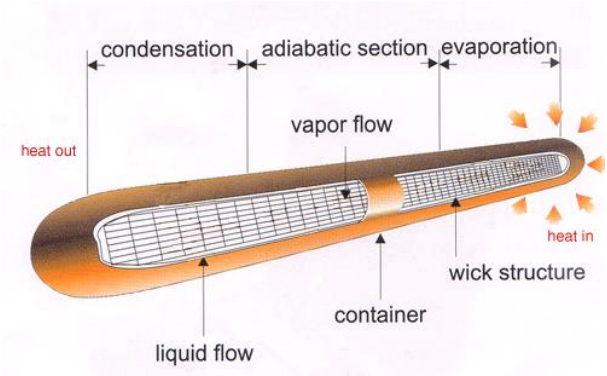

Figure 1. Heat Pipe Sections

3. Components of Heat Pipe

The main components of heat pipe heat exchanger are container, wick (or) capillary structure, working fluid which are shown in above figure.

A Container is the outer most covering which is to protect the inner components of heat pipe. The ultimate function of the heat pipe is to isolate the working fluid from outside environment in other words it is used to resist the working fluid made contact with the outside environment. It also prevents the reactions with the physical parameters like temperature, pressure etc., the commonly used the materials in the containers are Copper, Aluminium. Copper is the most widely used container which can works eminently between the temperatures (0 to 200℃).

TABLE.1: CONTAINER MATERIALS OF HEAT PIPE

CONTAINER MATERIAL	***WORKING FLUID***	***TEMP RANGE(◦C)***
Niobium	Rubidium	327 TO 827
	Potassium	527 TO 927
	Sodium	627 TO 1227
	Lithium	1027 TO 1627
304 stainless steel	Liquid nitrogen	-213 TO -173
	Mercury	227 TO 627
	Rubidium	327 TO 827
	Potassium	527 TO 927
	Sodium	627 TO 1227
Inconel	Sodium	627 TO 1227
Stainless steel	Ammonia	-73 TO 27
	Acetone	-52 TO 27
316 stainless steel	Sodium	627 TO 1227
Carbon steel	Ammonia	-73 TO 27
Nickel	Ammonia	-73 TO 27
Copper	Acetone	52 TO 127
	Water	52 TO 127
Brass	Acetone	52 TO 127
Aluminum	Liquid nitrogen	-213 TO -173
	Freon	-43 TO 27
	Ammonia	-73 TO 27
	Acetone	52 TO 127
Hastelloy	Sodium	627 TO 1227
Tungsten	Sodium	627 TO 1227
	Silver	1427 TO 1927
Glass	Acetone	52 TO 127

A wick is a porous structure made of material like nickel (or) copper, steel etc., it is also known as capillarity.

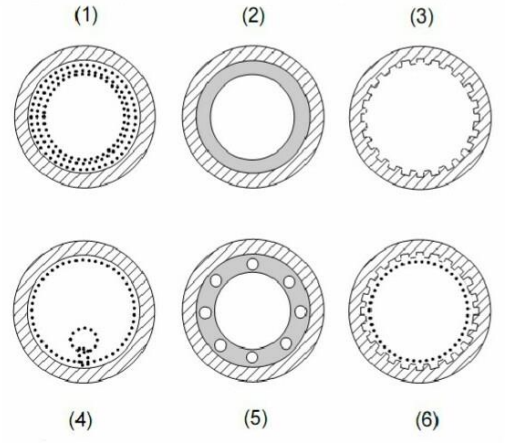

Figure 2.Various Structure of Wick

(1) Net structure
(2) Sinter structure
(3) Open channel structure
(4) to (6)-combined structure

Capillary is the word derived from the Latin word. Capillaries, means "of or resembling hair". It says the meaning tiny, hair like structure Net structure capillary tubes are very small having a net likes structure having many pores. Sinter structure is a tiny structure hence the pressure in the capillary is very high and the main disadvantage in this structure is to have bubbles which are closing the pores present in the capillary is high. Open channel structures have very low pressure losses but it also have the disadvantage that the liquid is carried out by the vapor from the channel before it reaches the hot side. The different type of capillary structures shown in figure: 2

4. Solar Collector

Solar collector is a device for capturing the solar radiation. Solar radiation is energy in the form of electromagnetic radiation from the infrared(long) to the ultraviolet (short) wavelengths.The solar collector is the main part of a solar thermal system, that transforms solar radiant energy into heat that can be used for heating swimming pools, hot water preparation, space heating and even as heat for industrial processes. Basically it can be distinguished between three types of collectors

• Uncovered (unglazed) collectors
• Flat plate collectors
• evacuated tubular collectors

In addition to these three basic types there also exist special collector designs for medium to high temperature applications like parabolic trough collectors or Fresnel collectors.

✓ Solar Collector Work

A Solar collector is basically a flat box and is composed to three main parts, a transparent cover, tubes which carry a coolant and an insulated back plate. The solar collector works on the greenhouse effect principle; solar radiation incident upon the transparent surface of the solar collector is transmitted through though this surface. The inside of the solar collector is usually evacuated, the energy contained within the solar collect is basically trapped and thus heat the coolant contained within the tubes are usually made from copper, and the back plate is painted block to help absorb solar radiation. The solar collector is usually insulated to avoid heat losses.

✓ Compatible Material (Working Fluid)

The fluid mass is chosen so that the heat pipe contains both vapor and liquid over the operating temp range. In a standard heat pipe, the condensed liquid is returned to the evaporator using a wick structure exerting a capillary action on the liquid phase of the working fluid. The different type of compatibility material shown in table: 2.

TABLE.2: WORKING FLUIDS

WORKING FLUID	COMPATIBLE MATERIAL	INCOMPATIBLE MATERIAL
Water	Stainless steel, Copper, Silica	Aluminium, Inconel.
Ammonia	Aluminium, Stainless Steel, Nickel, Iron	_
Methanol	Stainless Steel, Iron, Copper, Silica	Aluminium
Freon 11	Aluminium	_
Freon 21	Aluminium, Iron	_
Freon 113	Aluminium	_
Heptane	Aluminium	_
Sodium	Stainless Steel	Titanium

✓ **Requirements of working Fluids**

- Good thermal stability.
- High latent heat.
- High thermal conductivity.
- Low liquid and vapor viscosities.
- High surface tension.
- Acceptable freezing and pour point.
- Vapor pressure not too high or low over the operating temperature range.
- Compatibility with wick & wall material.

5. Nano Fluid

A recent advancement in nanotechnology has been introduction of Nano fluids, which is a colloidal suspension of nanometre-sized solid particles instead of common working fluids. A Nano fluid is a fluid containing nanometre-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles used in a base fluid. The nanoparticles used in the Nano fluids are typically made of metals, oxides, carbides, or carbon nanotubes.

✓ **Concepts of Nano Fluids**

Conventional heat transfer fluids have inherently poor thermal conductivity compared to solids. A conventional fluid that contains mm-or µm-sized particles do not work with the emerging "miniaturized" technologies because they can clog the tiny channels of these devices. Modern nanotechnology provides opportunities to produce nanoparticles. Nano fluids are a new class of advanced heat- transfer fluids engineered by dispersing Nano particles smaller than 100 nm (nanometre) in diameter in conventional heat transfer fluids. Solids have thermal conductivities that are orders of the large magnitude.

✓ **Insulated Material**

A material that reduces or prevents the transmission of heat or sound or electricity to the surrounding. The different types of insulating materials shown in table: 3

TABLE 3 : Insulating Materials

Insulation Material	**Temperature range**			
	Low		**High**	
	ºC	ºF	ºC	ºF
Calcium Silicate	-18	0	650	1200
Cellular Glass	-260	-450	480	900
Elastomeric Foam	-55	-70	120	250
Fiber Glass	-30	-20	540	1000
Mineral Wool, ceramic Fiber	-	-	1200	2200
Mineral Wool, Glass	0	32	250	480
Mineral Wool, Stone	0	32	760	1400
Phenolic Foam	-	-	150	300
Polyisocyanurate, Polyiso	-180	-290	150	300

✓ **Properties Of Nano fluids**

Nano fluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, hybrid- power engine then the enhancing functions and properties by combining and controlling interactions. Then the Nano fluids contain materials size is 1-100 nm it is one of the properties of the Nano fluids. A Nano fluid is a compatible and non-compatible material. High latent heat. High thermal conductivity. Low liquid and vapor viscosities. High surface tension. Acceptable freezing and pour point.

6. Literature Review

Raghurajsinh. B. parmar et al [1] explained the performance of an evacuated tube collector with heat pipe technology. This machinery mainly used for hot water creation. Because it gives more efficiency, less heat loss compared to the other technology.

Kumudini Gharge et al [2] demeanor the act of heat pipe in solar collector and discussed about the experimental setup, working fluid. The nano fluid used as the working fluid of the heat pipe. Use of the heat pipe in solar collector with nano fluid and the thermal efficiency of the system also discussed.

M.A. Sabiha et al [3] discussed about solar energy and evacuated heat pipe solar collector and its applications. the latest developments of the heat pipe in solar collector also reviewed in this paper. The evacuated tube having a high efficiency so we can use this type of

heat pipe at high operating temperature and based on the working fluid the performance of heat pipe will be varied.

Mujawar.N.H. et al [4] presented the performance of evacuated heat pipe in solar collector with nano fulid. Flat plate or evacuated tube solar collector used under solar energy it is mainly used for heating and cooling function. The evacuated tube solar collector performs 20-45% more efficient than flat plate solar collector. Due to their high efficiency it may use year round, even in high humidity, cold temperature and in poor weather conditions.

F. Mahdjuri [5] investigated about the solar collector, heat pipe, critical point, selective coating, rectangular characteristics and economical evaluation. In order to avoid the impediment in the operation for super heating the heat pipe to use the thick liquid. Condensation effect will disappear above the critical temperature. Then the temperature range of the working fluid also discussed.

S .Seshan et.al [6] presented the heat pipes – concepts, materials and applications. The heat pipe is the new inventive construction characterized by its ability to transfer large amount of heat through comparatively small cross-sectional areas with very small temperature difference. It also possesses high thermal conductance and low thermal impedance. The different working fluids and container materials also discussed in this paper.

Amir faghri [7] proposed in review and advances in heat pipe science and technology. This paper review that the heat pipe, heat pipes analysis and simulations. geometric modeling, analysis, and tentative imitation of heat pipes have drastically progressed due to a great extent greater sympathetic of various physical phenomena in heat pipes as well at the same time as advances in computational and investigational methodologies.

M. Hammed [8] describes the performance of flat plate solar collectors by heat pipe. The heat pipes are the valuable device in heat transfer industry as an economical heat transfer device. The heat pipes are mainly used for heat recovery purpose.

Abhiject A. pawer et al [9] proposed a thermal performance of wickless heat pipe solar collector with surfactant added to Nano fluid. The thermal performance of the heat exchanger can be enhanced by heat transfer technique. The heat transfer technique classified two types including requires external source methods and not requires external source method. These methods are followed for improvement of heat transfer performance.

Sotersis A. kalogirou [10] presented various types of solar thermal collector and its applications and an analysis of the environmental crisis related to conventional energy source and benefits of renewable energy source. The optical, thermal and thermodynamic scrutiny of collectors is also presented with methods to estimate their performance. The typical applications of heat pipes, desalination and chemistry applications.

C. B Sobhon et al [11] investigated on the study of micro heat pipes and discussed about various designs, fabrication methods, operational environments and applications.

Mehmet Akyput [12] developed the heat pipes for solar water heater. Heat pipe was integrated into a trial product solar water heater developed for the purpose for under actual insulation circumstances. The development of heat pipe, heat pipe container materials, working fluid, wick structures and sections of the heat pipe also discussed in this paper.

Jorge Facao et al [13] presented a novel prototype solar collector, using a plate heat pipe and the effect of condenser heat transfer on the energy performance. The rectangular channel in the heat pipe is known as condenser. The channel is inclined and heat transfer occurred by this channel.

A .Jahanbakhash et al [14] considered the construction and working fluid of the heat pipe. The heat pipe have been constructed and tested using the solutions of ethanol and water as the working fluid at different tilt angle and concentrations. The experimental tests were conceded out to scrutinize the effect of ethanol concentration and the use of wick inside the heat pipe to ensure an incessant act of a heat pipe. In this case 52% of efficiency obtained for the heat pipe operated in the solar collector and the collector having a tilt angle 35º.

Y. Cao et al [15] discussed about the wickless heat pipe and the concept of boiling heat transfer mechanism in narrow space is described. Based on the concept of the boiling heat transfer in a narrow space, heat pipes were fabricated and tested. heat pipe was a wickless heat pipe

that is able to spreading heat from a rigorous heat source to a large surface area with low industrialized costs.

Kusure Balasao .D [16] considered the heat transfer enhancement in heat pipe using nano fluid and the paper summaries the recent work in investigational and conjectural heat transfer characteristic of Nano fluid. The Nano fluid is a stable solid–liquid deferral formed by mixing nanoparticles with the customary working fluid and many studies have shown that Nano fluid can in actual fact develop the heat transfer performance of heat exchange applications.

III. RESULT AND DISCUSSION

1. Experimental Setup

Heat pipe plays a major role in solar collector for the purpose of reducing the over heat of the solar collector. The schematic diagram shows that the experimental setup of solar heat pipe collector. The basic characteristics and specifications of the different components used in the wickless heat pipe collector. Nano fluid is a working fluid as solar collector. The sides and back of solar collector is properly insulated by glass wool, mineral wool, flexible elastomeric foams. Then the heat pipe having some specifications. Inner dia of the heat pipe is 0.011m and the outer dia of the heat pipe is 0.013m. The length of heat exchanger is 0.30m.All collectors are faced towards south 14 degree inclination from the horizontal. The experimental setup shown in figure: 3

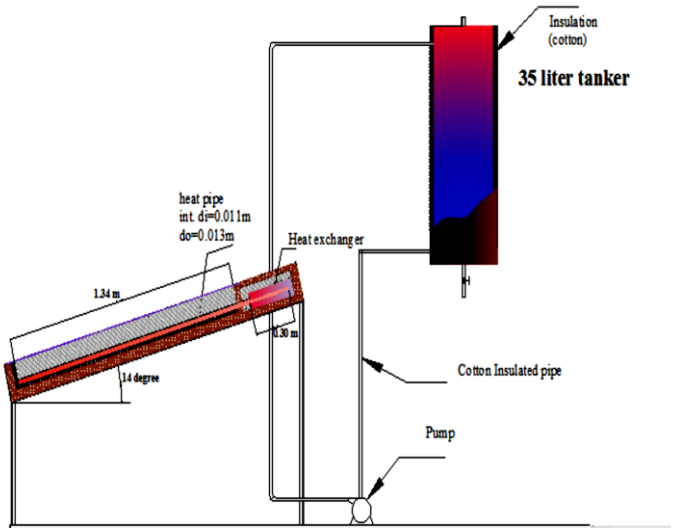

Figure 3. Experimental Setup

2. Working

The components of a typical cylindrical wickless 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 are 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 into 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. Evacuated Heat Pipe

The evacuated heat pipe solar collectors operate differently than the other collectors. These solar collectors consist of a heat pipe inside a vacuum-sealed tube. The tube contains a sealed copper pipe. These evacuated tubes are mounted, the metal tips up, into the heat exchanger (manifold). Protruding from the top of tube is a metal tip attached to the sealed pipe (condenser). As the sun shines on the black surface of the fin, the liquid inside the heat pipe is heated. The nontoxic liquid used as working fluid. The heated liquid in the evaporator section get vaporized then the vaporized vapor rises to the top of the pipe. The top section of the pipe is known as condenser section. The condenser section condenses the vapor into water. This process is repeated continuously by a return feed mechanism of the condensed fluid return to the heat region. It gives more efficiency than flat heat pipe. The evacuated heat pipe shown in figure: 4

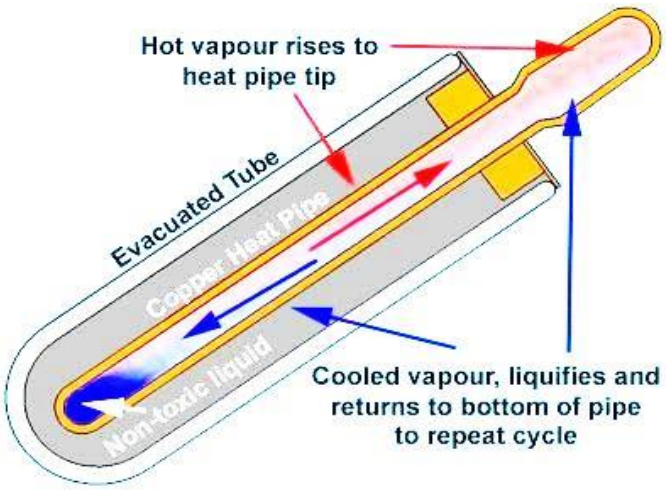

Figure 4. Evacuated Heat Pipe Structure

IV. DISCUSSION

In this paper we discuss about solar energy and its uses. Then we investigated about Nano fluids, its properties and Nano fluids used in heat pipes. Advantages of Nano fluid use in heat pipe. It is increased thermal efficiency and high dispersion stability. We analysed about evacuated heat pipe. The prime merit of this pipe is thermal efficiency is high then flat heat pipe.

IV. CONCLUSION

This paper presents an overview of heat pipe in solar collector using Nano fluids and its applications. Studies of Nano fluids reveals high thermal conductivities and heat transfer co-efficient compared to those of conventional fluids. Then discussed the evacuated heat pipe in solar collector. The evacuated tube solar collectors execute better in comparison to flat plate solar collector and this is the better choice for domestic utilization since of its simplicity and low cost. Then we analysed Nano fluids, its properties and types of Nano fluids using in heat pipe. Nano fluid contains high thermal conductivity and low evaporation point. So in future efficiency of heat pipes will increase.

V. ACKNOWLEDGEMENT

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