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Thermal Performance And Analysis of a Solar water Heating System With Heat Pipe Evacuated Tube Collector

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Abstract: Renewable energy is mostly used by many countries now days for energy generation and save our environment as well as save conventional fuel resources. Solar energy is one of the most efficient, clean and affordable energy alternatives available today. With the current concerns about global warming and ever-increasing energy rates, countries are seriously looking for domestic and industrial usage of solar energy. Cooling, refrigeration, and air conditioning processes are considered essential needs and major requirements for all human beings in our world today.

In the present study, a detail review of the application of solar energy by using evacuated tube collector with heat pipe technology for hot water generation has been carried out. The utilization of solar energy for hot water generation system by Evacuated Tube Collector would help in improvement of energy economics, energy consumption and energy efficiency.

In this project thermal analysis is to determine the temperature distribution and heat flux for glass tubes. This technology used mainly for hot water generation which is further used for different purpose compared to any other collector or technology because of higher efficiency, less heat loss, less friction and many more advantages.

Key Words: Solar Water Heater, Thermal Performance, evacuated Tube Collector, Analysis, PRO-E Design Software

1. Introduction

Solar water heating (SWH) is the conversion of sunlight into heat for water heating using a solar thermal collector. A variety of configurations are available at varying cost to provide solutions in different climates and latitudes. SWHs are widely used for residential and some industrial applications.

A sun-facing collector heats a working fluid that passes into a storage system for later use. SWH are active (pumped) and passive (convection-driven). They use water only, or both water and a working fluid. They are heated directly or via light-concentrating mirrors. They operate independently or as hybrids with electric or gas heaters. In large-scale installations, mirrors may concentrate sunlight onto a smaller collector.

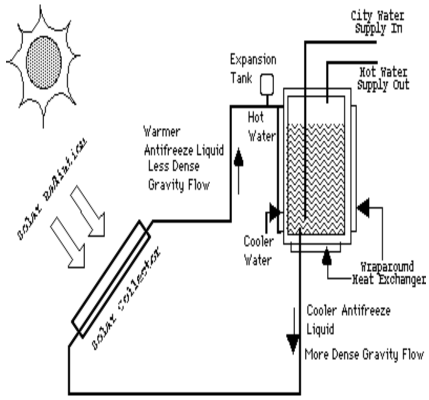

FIG 1: SOLAR WATER HEATING

1.1 Working Principle

Solar water heating systems include storage tanks and solar collectors. There are two

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types of solar water heating systems: active, which have circulating pumps and controls, and passive, which don't.

1.1.1 ACTIVE SOLAR WATER HEATING SYSTEMS

There are two types of active solar water heating systems:

Direct circulation systems

Pumps circulate household water through the collectors and into the home. They work well in climates where it rarely freezes.

Indirect circulation systems

Pumps circulate a non-freezing, heat-transfer fluid through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates prone to freezing temperatures.

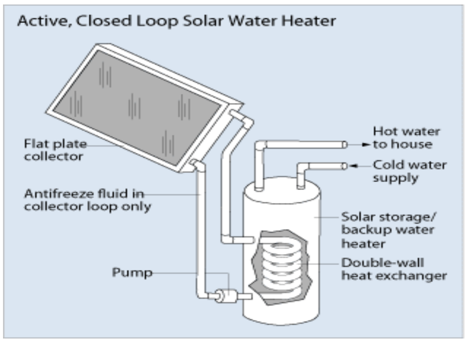

Fig 2: Active Closed Loop Solar Water Heater

1.1.2 PASSIVE SOLAR WATER HEATING SYSTEMS

Passive solar water heating systems are typically less expensive than active systems, but they're usually not as efficient. However, passive systems can be more reliable and may last longer. There are two basic types of passive systems:

Integral collector-storage passive systems

These work best in areas where temperatures rarely fall below freezing. They also work well in households with significant daytime and evening hot-water needs.

Thermosyphon systems

Water flows through the system when warm water rises as cooler water sinks. The collector must be installed below the storage tank so that warm water will rise into the tank. These systems are reliable, but contractors must pay careful attention to the roof design because of the heavy storage tank. They are usually more expensive than integral collector- storage passive systems.

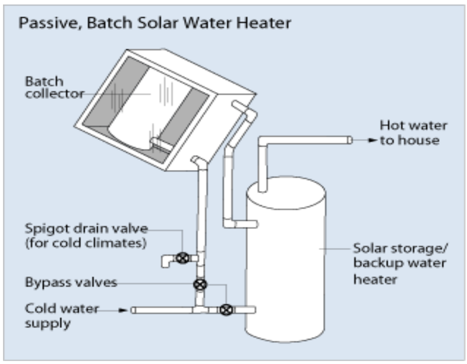

Fig 3: Passive Batch Solar Water Heater

1.1.3 Evacuated-tube solar collectors

They feature parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits radiative heat loss. These collectors are used more frequently for U.S. commercial applications.

Solar water heating systems almost always require a backup system for cloudy days and times of increased demand. Conventional storage water heaters usually provide backup and may already be part of the solar system package. A backup system may also be part of the solar collector, such as rooftop tanks with thermosyphon systems. Since an integral-collector storage system already stores hot water in addition to collecting solar heat, it may be packaged with a tankless or demand-type water heater for backup.

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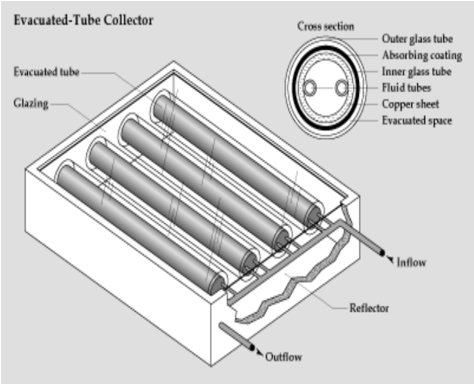

Fig 4: Evacuated tube Collector

2. MODELLING AND ANALYSIS

The solar water heater is modelled using the given specifications and design formula from data book. The isometric view of solar water heater is shown in below figure. The solar water heater outer casing body profile is sketched in sketcher and then it is revolved up to 360^0 angle using revolve option and tubes are designed and assemble to in solar water heater using extrude option.

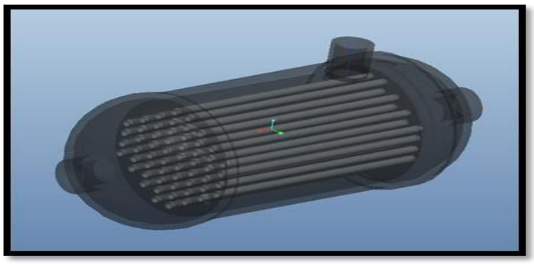

Fig 5: Solar Water Heater 3D Model

2.1 CFD ANALYSIS OF SOLAR WATER HEATER

Mass Flow Rate - 0.006, 0.008, 0.015 Kg/s

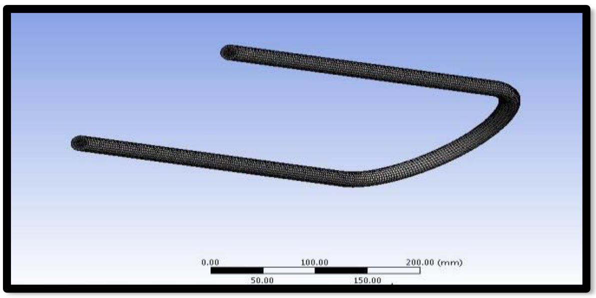

Fig 6:

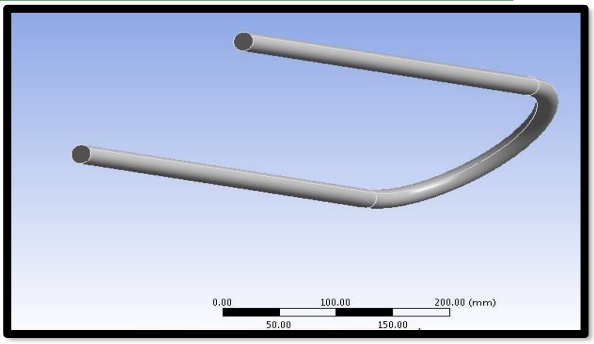

Fig 7:

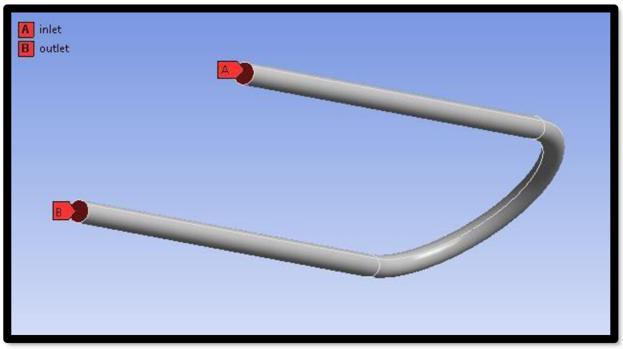

Fig 8:

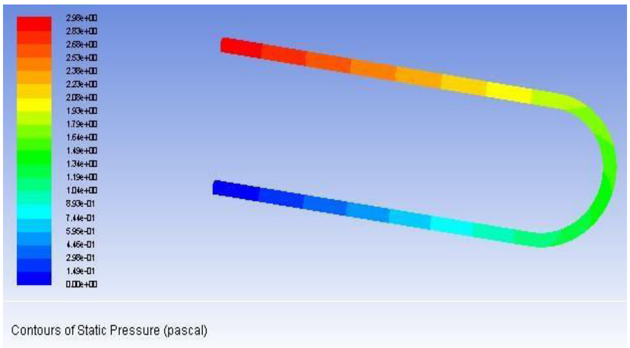

Fig 9: PRESSURE MASS FLOW RATE – 0.006m/s

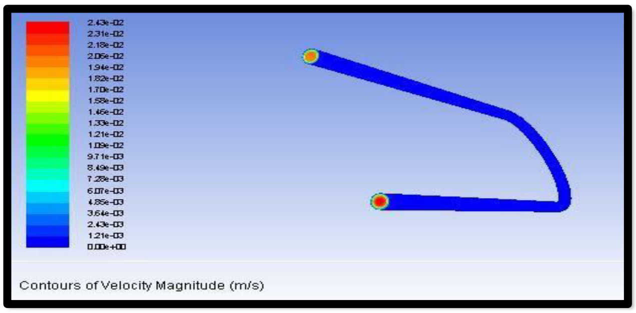

Fig 10: VELOCITY MASS FLOW RATE – 0.006m/s

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MASS FLOW RATE

Mass Flow Rate	(kg/s)
inlet	0.0059999996
interior-____msbr	-2.503412
outlet	-0.0060066455
wall-____msbr	0
Net	-6.6459179e-06

HEAT TRANSFER RATE

Total Heat Transfer Rate	(w)
inlet	1878.1362
outlet	-1880.2151
wall-____msbr	0
Net	-2.0788574

Table 1: For 0.006 Kg/s Mass flow rate & Heat Transfer Rate Performance

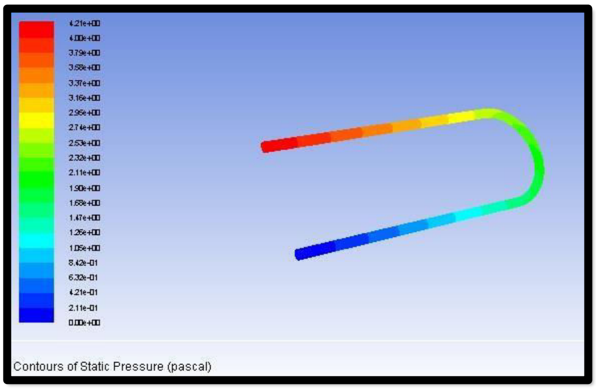

Fig 11: Pressure Mass Flow Rate 0.008 Kg/s

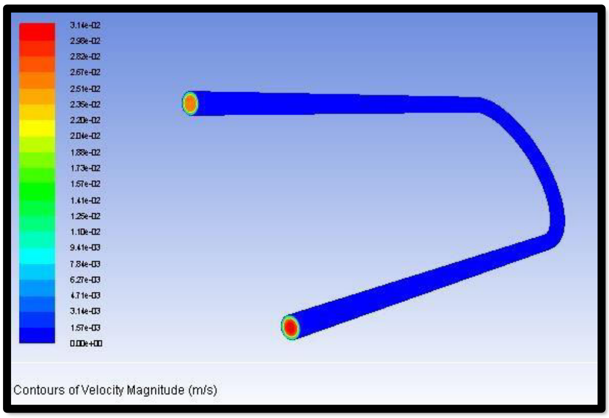

Fig 12: VELOCITY MASS FLOW RATE – 0.008kg/s

3. THERMAL ANALYSIS OF SOLAR WATER HEATER

MASS FLOW RATE

Mass Flow Rate	(kg/s)
inlet	0.0080000013
interior-____msbr	-3.3359661
outlet	-0.0079953074
wall-____msbr	0
Net	4.6938658e-06

HEAT TRANSFER RATE

Total Heat Transfer Rate	(w)
inlet	2504.1824
outlet	-2502.7114
wall-____msbr	0
Net	1.4709473

Table 2: For 0.008 Kg/s Mass flow rate & Heat Transfer Rate Performance

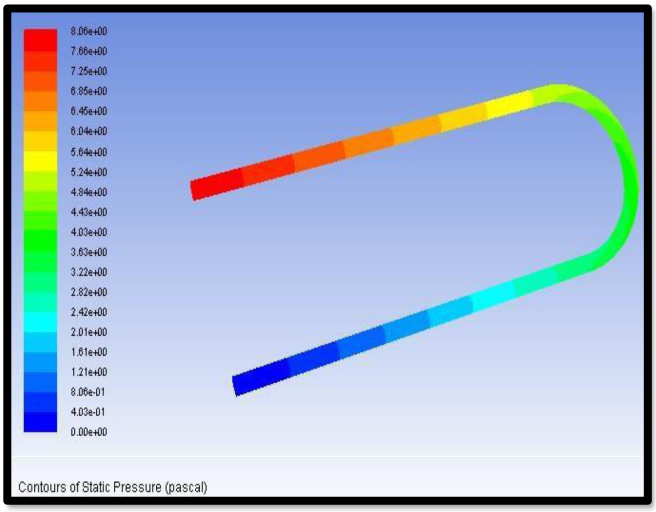

Fig 13: Pressure Mass Flow Rate 0.015 Kg/s

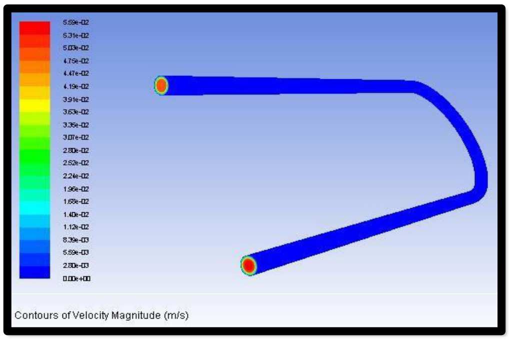

Fig 14: VELOCITY MASS FLOW RATE – 0.015kg/s

MASS FLOW RATE

```
              Mass Flow Rate                    (kg/s)
 -------------------------------- --------------------
                         inlet             0.014999997
              interior-____msbr             -6.2576375
                         outlet           -0.014996917
                    wall-____msbr                    0
           ---------------------- --------------------
                            Net          3.0798838e-06
```

HEAT TRANSFER RATE

```
 Total Heat Transfer Rate                           (w)
 -------------------------------- --------------------
                          inlet              4695.3403
                         outlet             -4694.3867
                   wall-____msbr                     0
           ---------------------- --------------------
                            Net             0.95361328
```

4. RESULTS & CONCLUSIONS

Comparing the thermal properties of the water heaters, the following results are obtained.

Copper material properties

Thermal conductivity	=	**385w/m-k**
Specific heat	=	**0.385j/g^{0}C**
Density	=	**0.00000776kg/mm^3**
Aluminium material properties		
Thermal conductivity	=	**210w/m-k**
Specific heat	=	**0.9000j/g^{0}C**
Density	=	**0.0000026989kg/mm^3**
Aluminium alloy 6061 material properties		
Thermal conductivity	=	**180w/m-k**
Specific heat	=	**0.896j/g^{0}C**
Density	=	**0.00000270kg/mm^3**

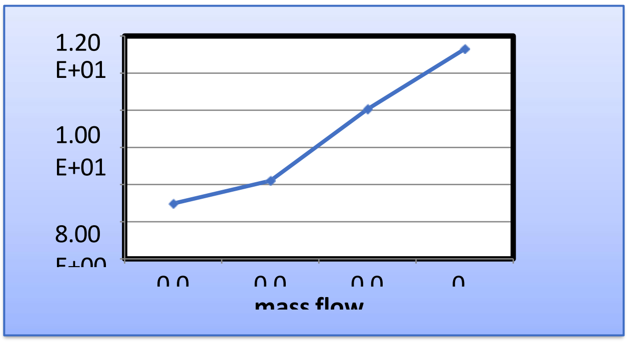

Fig 15: PRESSURE PLOT GRAPH

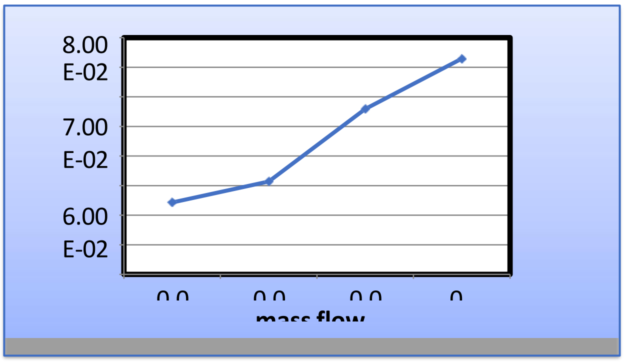

Fig 16: VELOCITY PLOT GRAPH

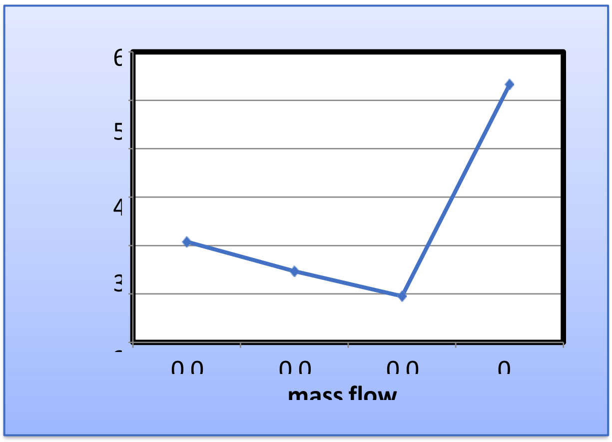

Fig 17:MASS FLOW RATE GRAPH

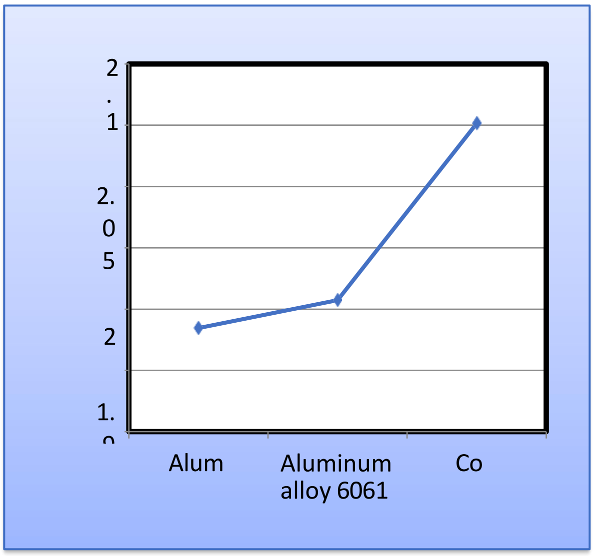

Fig 18: HEAT TRANSFER RATE PLOT

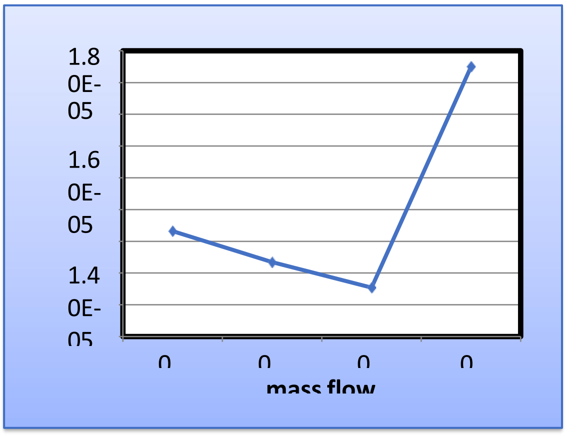

Fig 19: MASS FLOW RATE GRAPH

Table 3: CFD ANALYSIS

Flow rates (Kg/s)	Pressure (Pa)	Velocity (m/s)	Mass flow rate (kg/s)	Heat transfer rate (W)
0.006	2.98e+00	2.43e-02	6.6459e-06	2.0788574
0.008	4.21e+00	3.14e-02	4.6938e-06	1.4709473
0.015	8.06e+00	5.59e-02	3.07988e-06	0.95361328
0.02	1.13e+01	7.29e-02	1.69929e-05	5.3261719

Table 4: THERMAL ANALYSIS

Material	Temperature (^0C)		Heat flux (w/mm^2)
	Max	Min	
Aluminum	100	89.189	1.8845
Aluminum alloy 6061	100	90.041	1.9072
Copper	100	95.191	2.0515

5. CONCLUSIONS

In this thesis the steam flow in solar water heater tubes is modelled using PRO-E design software. The thesis will focus on thermal and CFD analysis with different flow rates (0.006, 0.008, 0.015& 0.02m/s). Thermal analysis done for the solar water heater by aluminium, aluminium alloy 6061& copper at water heat transfer coefficient values.

By observing the CFD analysis the pressure drops, velocity, mass flow rate & heat transfer rate increases by increasing the inlet flow rates.

By observing the thermal analysis, Heat flux value is more for copper material than aluminium and aluminium alloy 6061.

So, we can conclude the copper material is better for solar water heater.

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