Analytical Investigations of Solar Water Heating using Heat Pipe with Evacuated Tubes

Sakthivel M, P Rajanikanth Reddy

Abstract: ***Solar water heating (SWH) apparatus converts sun strength into heat for heating water using a sun thermal collector. A solar faced solar collector heats a fluid that passes thru a garage gadget for later use. In this gift have a look at, a detailed evaluation for the software of sun energy the use of evacuated tube collector incorporated with warmness pipe era for warm water generation is being finished. The usage of sun energy for era of warm water with the aid of Evacuated Tube Collector could help in improving the power intake, power economics and energy performance. This evaluate focuses on Evacuated Tube with Heat Pipe Technology. The observe includes thermodynamic equation to locate the performance. In this thesis the evacuated tube collector with warmness pipe modeling are modeled using creo parametric software and analyzed in ANSYS software at specific mass float rate (0.047 & 0.167 kg/s) and at unique temperatures on the month(January to December). CFD analysis is executed to determine the velocity, pressure drop, mass waft fee, heat transfer fee and heat transfer coefficient for evacuated tube collector with warmth pipe. Thermal analysis is carried to determine the temperature distribution and warmth flux at exceptional month (January to December).***

Index Terms: Solar Hot Water System, Evacuated Tube Collectors, Hot Pipe.

I. INTRODUCTION

Solar water heater is a tool that may be used to converts daylight which will warmness the water. A form of configurations are to be had in sun water heating gadget to offer exceptional climates. A solar water heating machine includes:

1.A solar collectors mounted at the roof,
2.A tank is used to save the water,
3.A circulating pump is used to carry sun electricity from the collector and thermal regulator is used.

Working Principle of Solar Water Heating System:

In, solar water heating machine, the recent water is heated with the aid of sun thermal power. In that the decrease density of water is actions upwards and higher density of the water moves Downwards to the tank due to its gravity head. A creditors are arranged series-parallel mixture to get higher quantity of the water. Solar water warmers can be of kinds based totally on creditors gadget. They are

1.Flat Plate Creditors
2.Evacuated Tube Creditors.

Revised Manuscript Received on June 07, 2019.

Sakthivel M, Mechanical Engineering, Koneru Lakshmaiah Educational Foundation, Guntur, India.
P Rajanikanth Reddy, Mechanical Engineering, Koneru Lakshmaiah Educational Foundation, Guntur, India.

Flat Plate Creditors:

Flat plate creditors are also used in solar water heating device. Flat plate collector is converts radiant sun strength from the sun into warmth energy using greenhouse impact.

A sun flat plate consists of heat soaking up plate, large sheet of copper and aluminium are used. Flat plate collectors can warmth the fluid inner the use of both direct or indirect daylight.

Evacuated Tube Creditors:

Evacuated tube solar creditors converts power from the sun in to usable warmness in solar water heating device .The energy may be utilized in domestic and business warm water heating, pool heating ,space heating and even aircon .Evacuated tube solar creditors are available inside the sizes of 10, 20, 22 and 30 .

Working:

1.An Evacuated tube made of parallel tubes, one is inner tube and any other is outer tube.
2.Inner tube is lined with selective coating and outer is covered with obvious.
3.Both internal and outer tubes have minimal reflection houses.
4.The internal tube get heated at the same time as sunlight passes thru the outer tube and to hold the heat inside internal tube, a vacuum is created which lets in simplest sun radiation.
Five.
5.In order create vacuum the 2 tubes are fused together at the pinnacle and the existed air is pumped out.
6.Thus the warmth stays inside the inner pipes and collects the solar radiation performance.
7.Therefore an evacuated tube solar collector is more efficient collector.

Analytical Investigations Of Solar Water Heating Using Heat Pipe With Evacuated Tube Collectors

Thermosiphon solar water heater

A sun water heater that is set up in a house of Belgium , A type of configurations are to be had at varying price to offer answers in extraordinary climates and latitudes. Solar water heating machine is widely used for residential and a few industrial programs.

The form of complexity and size of a solar water heating device is calculated by way of the usage of:

1.Change in ambient temperature and irradiation among summer season and winter.

2. Change in ambient temperature in the course of the day and night time cycle.

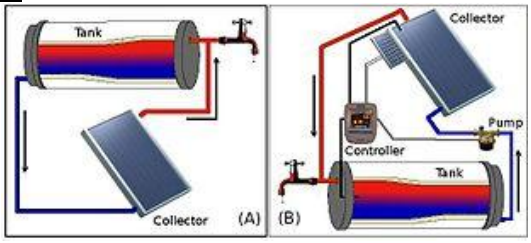
3. Possibility for the potable water and collector fluid overheating or freezing.

The minimum necessities for the device are decided via the amount, temperature of warm water required in the course of winter, whilst a structures outgoing and incoming water temperature are at their lowest temperature. The most output of the machine is decided by using the want of preventing the water in the machine from becoming too hot. Another decrease-upkeep concept is the 'drain-returned'. No anti-freeze is required; rather, all the piping is sloped to cause water to empty lower back to the tank. The tank is not pressurized and operates at atmospheric pressure. As quickly because the pump off, the float is reverses and the pipes empty earlier than freezing can occur.

How a solar hot water system works

Heat transfer:

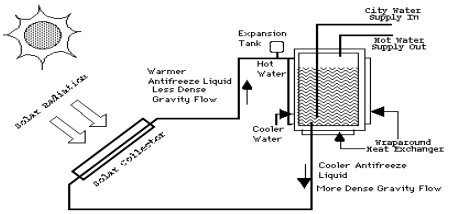
Direct:



It is also known as open-loop system.It uses a pump to circulate the water into the system.The cold water is pumped directly from the home to water storage, while the hot water leaves the flat plate collector and return back to storage tank in continuous. From the tank the water is pumped back to house and the water is used as usable water.While the passive direct hot water system doesn't uses a pumps to transfer the heat into storage tank.In open-loop system which is used to natural force of gravity is used to circulate the water. While the open-loop system is used flat plate collectors and combined with horizontally storage tank.

Indirect:

Indirect or closed loop systems use a heat exchanger to transfer warmth from the warmth-switch fluid to the potable water. The most commonplace HTF is an antifreeze/water mix that non-poisonous propylene glycol. After heating inside the panels, the warmth-transfer fluid travels to the warmth exchanger, where its warmness is transferred to the potable water. Indirect structures offer freeze protection and commonly overheat safety.In sun water heating system are used each lively (pumped) and passive (convection-pushed). They use water handiest as a running fluid.They are heated directly or thru mild-concentrating mirrors. They operate independently or as hybrids with gasoline warmers. In large-scale installations, mirrors pay attention sunlight onto a smaller collector.



Working principle

Solar water heating structures contains storage tanks and sun collectors. There are two types of solar water heating systems are there one is active, that have circulating pumps and controls, and passive, which don't use both circulating pumps and controls.

ACTIVE SOLAR WATER HEATING SYSTEMS

Two sorts of solar water heating structures are to be had.

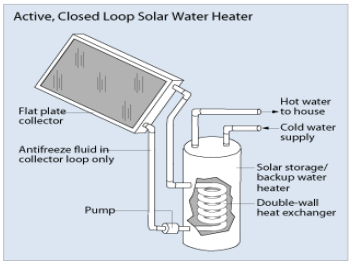
Direct stream systems:

There are so many flow structures are there one is direct movement gadget. The direct circulation machine is closed loop system.

The gadget is quite simple, a single loop is presented in the direct stream system and moves the water from domestic to be heated and lower back it to again.

Indirect movement systems:

Indirect move device is greater complicated than direct circulate gadget. There is a closed loop among solar collector and garage tank. The liquid actions to the solar collector and again to the garage tank, via transferring to the garage tank the temperature is increases very high.



PASSIVE SOLAR WATER HEATING SYSTEMS

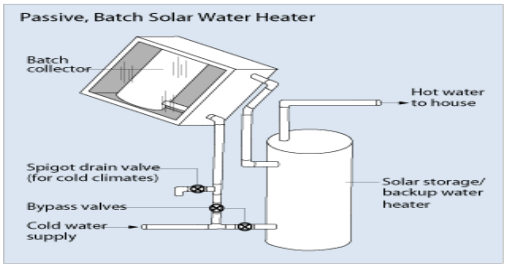
Passive solar water heating structures is less pricey than energetic systems, but they are normally now not as green. However, passive systems may be extra dependable.SThere are simple kinds of passive structures:

Integral collector-storage passive systems:

These work nice in areas where in temperatures hardly ever fall under freezing. These are work properly in families with substantial day time and evening time with hot-water desires.

Thermosyphon structures:

Thermosyphon machine is generally used and commonly to be had solar warm water machine, use this as flat plate and storage tank combination. The care have to be taken whilst putting in the device. Thermosyphon is operating as a same precept as passive direct thermosyphon machine, besides the
garage tank within the thermosyphon is away inside the system and the ultimate principle is identical.



Literature Survey:

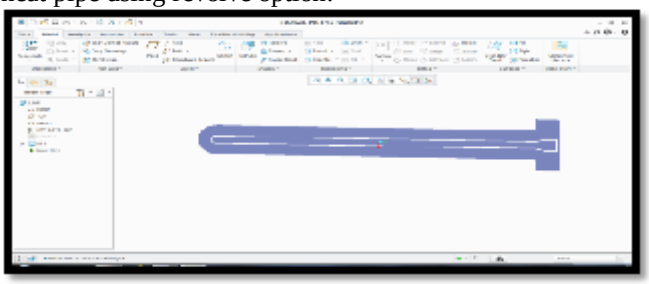
The high fossil power consumption now not handiest reasons the scarcity of energy however also increases problems of international warming. Increasing desires of fossil fuel might be decreased thru the usage of sun strength the usage of sun creditors.Indonesia has the plentiful potential for sun strength, however non-renewable power sources nonetheless dominate power consumption.Heat pipe as passive warmness switch device, evacuated tube sun collector is expected to heat up water for business and domestic utilization with out external strength deliver needed to flow into water within the solar collector. This studies is carried out to determine the thermal overall performance of heat pipe evacuated tube solar collector as solar water heater experimentally. The experiments are executed using stainless steel mesh as a wick cloth, and water and Al2O3-water and zero.1% nano-fluid as running fluid, and making use of inclination angles. To analyze the heat absorbed and transferred with the aid of the prototype, water at 30°C was circulated thru the condenser. Experimental outcomes indicates using Al2O3-water and 0.1% nano-fluid at distinct inclination angle gives the highest thermal performance, which offers efficiency as excessive and thermal resistance as little as five.32 °C/W. The use of nano-fluid as working fluid that enhances thermal performance of the solar water heating with excessive thermal conductivity of the operating fluid. The boom of the inclination perspective performs a function in the drainage of the condensate to the evaporator that ends in better thermal performance till the top-quality inclination attitude is reached.

II. MODELLING AND ANALYSIS

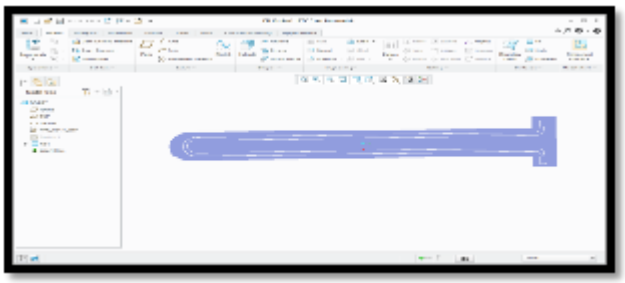
Models of heat pipe with evacuated tube

Using CREO parametric software

The heat pipe with evacuated tube is modeled using the specifications and design formula from data book. The isometric view of evacuated tube with heat pipe is shown in below figure. The evacuated tube with heat pipe 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 evacuated tube with heat pipe using revolve option.



SINGLE TYPE HEAT PIPE



U-bend type heat pipe

Drafting image

CFD ANALYSIS OF HEAT

Total Heat Transfer Rate	(W)
inlet	3940.9092
inlet6tt	3940.9033
outlet	-3995.4209
outlet.1	[illegible]
wall-_trm_srf	0
Net	-73.450684

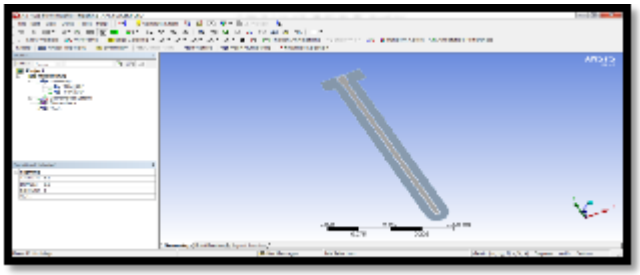
PI

PE WITH EVACUATED TUBE

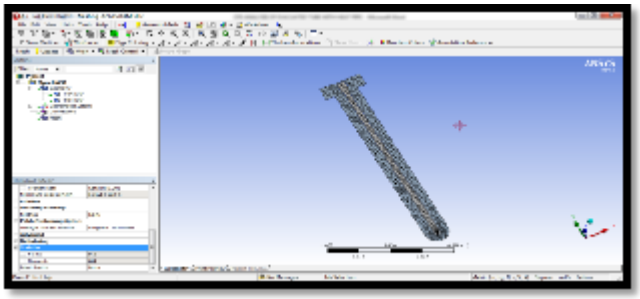
EVACUATED TUBE WITH SINGLE HEAT PIPE

Mass flow inlet – 0.047& 0.167kg/s

Temperature - January to December month

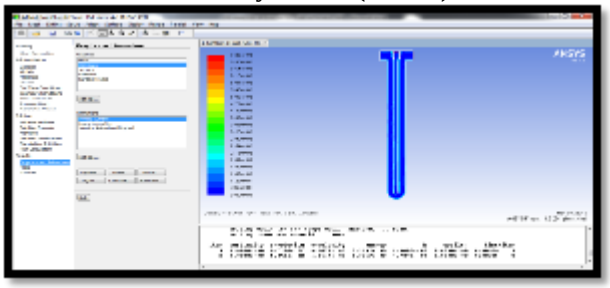


Imported model



Meshed model

Case 1: mass flow 0.047 kg/s
January month (20.2^{0}C)

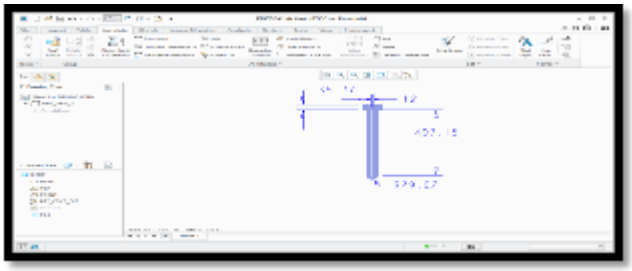


Heat transfer coefficient

Mass Flow Rate	(kg/s)
inlet	0.046999998
inlet6tt	0.046999998
interior-_trm_srf	-2.2123306
outlet	-0.047650078
outlet.1	-0.047225751
wall-_trm_srf	0
Net	-0.00087582692

Mass flow rate

Heat transfer rate



February month (24^{0}C)

Total Heat Transfer Rate	(W)
inlet	3940.9092
inlet6tt	4687.8125
outlet	-3995.2848
outlet.1	4710.289
wall-_trm_srf	0
Net	-76.69165

Heat transfer rate

March month (29.4^{0}C)

Total Heat Transfer Rate	(W)
inlet	3940.9092
inlet6tt	5749.2085
outlet	-3995.5012
outlet.1	-5776.6738
wall-_trm_srf	0
Net	-82.057373

Heat transfer rate

April month (35.7^{0}C)

Total Heat Transfer Rate	(W)
inlet	6987.4971
inlet6tt	6987.4883
outlet	7884.1416
outlet.1	-7821.0449
wall_trm_srf	0
Net	100.26013

Heat transfer rate

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

May month (39.7^{0}C)

Total Heat Transfer Rate	(W)
inlet	7773.7124
inletótt	7773.7895
outlet	-7881.2941
outlet.1	-7811.8283
wall-_trn_srf	0
Net	-144.85859

Heat transfer rate

June month (39.6^{0}C)

Total Heat Transfer Rate	(W)
inlet	7754.0502
inletótt	7754.0547
outlet	-7861.3[illegible]
outlet.1	-7791.31[illegible]
wall-_trn_srf	0
Net	-144.51318

Heat transfer rate

July month (34.9^{0}C)

Total Heat Transfer Rate	(W)
inlet	6830.25
inletótt	6830.2451
outlet	-6924.7383
outlet.1	-6868.0459
wall-_trn_srf	0
Net	-127.28986

Heat transfer rate

August month (32.9^{0}C)

Total Heat Transfer Rate	(W)
inlet	6937.1416
inletótt	6937.1362
outlet	-6526.1709
outlet.1	6960.0464
wall-_trn_srf	0
Net	-119.93945

Heat transfer rate

September month (33.3^{0}C)

Total Heat Transfer Rate	(W)
inlet	6515.7632
inletótt	6515.7688
outlet	6695.8838
outlet.1	-6547.0537
wall-_trn_srf	0
Net	121.41486

Heat transfer rate

October month (31.5^{0}C)

Total Heat Transfer Rate	(W)
inlet	6358.522
inletótt	6358.5142
outlet	6446.4[illegible]
outlet.1	6[illegible]
wall-_trn_srf	0
Net	-118.47852

Heat transfer rate

November month (27.2^{0}C)

Total Heat Transfer Rate	(W)
inlet	5316.7871
inletótt	5316.7827
outlet	5398.0164
outlet.1	-5342.29
wall-_trn_srf	0
Net	-99.837671

Heat transfer rate

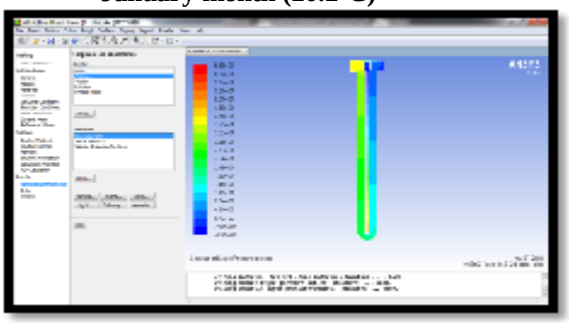
December month (22.8^{0}C)

Total Heat Transfer Rate	(W)
inlet	4451.9453
inletótt	4451.9408
outlet	-4518.5239
outlet.1	-4473.3145
wall-_trn_srf	0
Net	-82.949219

Heat transfer rate

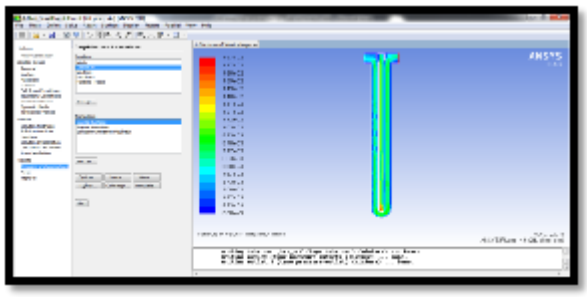
Case 2: mass flow 0.167 kg/s

January month (20.2^{0}C)

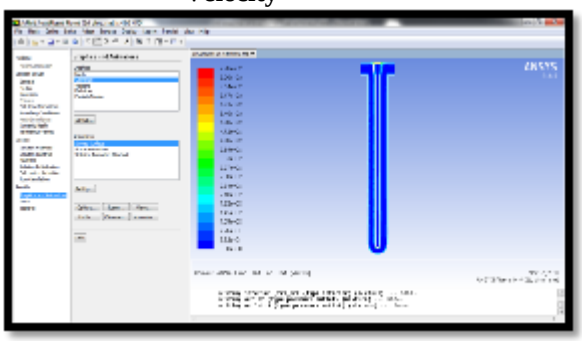


Pressure

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication



Velocity



Heat transfer coefficient

Mass Flow Rate	(kg/s)
inlet	0.167
inletótt	0.16699998
interior- trn srf	-8.2870654
outlet	-0.16876982
outlet.1	-0.1677953
wall _trn_srf	0
Net	0.0025651455

Mass flow rate

Total Heat Transfer Rate	(W)
inlet	14482.886
inletótt	14482.883
outlet	-14192.016
outlet.1	-14069.536
wall _trn_srf	0
Net	-255.04336

Heat transfer rate

February month (24^{0}C)

Total Heat Transfer Rate	(W)
inlet	16656.699
inletótt	16656.699
outlet	-16882.527
outlet.1	-16736.074
wall-_trn_srf	0
Net	-305.20813

Heat transfer rate

March month (29.4^{0}C)

Total Heat Transfer Rate	(W)
inlet	20428.823
inletótt	20428.823
outlet	-20706.055
outlet.1	-20525.465
wall-_trn_srf	0
Net	-375.47266

Heat transfer rate

April month (35.7^{0}C)

Total Heat Transfer Rate	(W)
inlet	24827.918
inletótt	24827.908
outlet	-25166.629
outlet.1	-24946.184
wall-_trn_srf	0
Net	-456.98633

Heat transfer rate

May month (39.7^{0}C)

Total Heat Transfer Rate	(W)
inlet	27621.492
inletótt	24827.912
outlet	-27998.412
outlet.1	-24946.184
wall-_trn_srf	0
Net	-495.19141

Heat transfer rate

June month (39.6^{0}C)

Total Heat Transfer Rate	(W)
inlet	27621.446
inletótt	24758.97
outlet	-27927.695
outlet.1	-24876.16
wall- trn srf	0
Net	-494.13867

Heat transfer rate

July month (34.9^{0}C)

Total Heat Transfer Rate	(W)
inlet	24869.186
inletótt	24869.184
outlet	-24888.336
outlet.1	-24884.859
wall _trn_srf	0
Net	-446.82617

Heat transfer rate

August month (32.9^{0}C)

Total Heat Transfer Rate	(w)
inlet	22872.398
inlet6tt	22872.484
outlet	-23184.882
outlet.1	-22981.475
wall-_trn_srf	0
Net	-420.75891

Heat transfer rate

Total Heat Transfer Rate	(w)
inlet	15818.62
inlet6tt	15818.62
outlet	-16083.062
outlet.1	15893.992
wall-_trn_srf	0
Net	289.75391

Heat transfer rate

September month (33.3^{0}C)

Total Heat Transfer Rate	(w)
inlet	23151.758
inlet6tt	23151.756
outlet	-23407.813
outlet.1	-23262.039
wall- trn srf	0
Net	-425.83789

Heat transfer rate

October month (31.5^{0}C)

Total Heat Transfer Rate	(w)
inlet	22593.453
inlet6tt	22593.494
outlet	-22940.916
outlet.1	-22780.672
wall-_trn_srf	0
Net	-415.49023

Heat transfer rate

November month (27.2^{0}C)

Total Heat Transfer Rate	(w)
inlet	18891.566
inlet6tt	18891.566
outlet	-19148.244
outlet.1	-18981.619
wall-_trn_srf	0
Net	-346.73047

Heat transfer rate

December month (22.8^{0}C)

Single Type Heat Pipe CFD Analysis Results:
Mass Flow Inlet 0.047 kg/s:

Mass Flow Inlet(kg/s)	Pressure (Pa)	Velocity(m /s)	Heat transfer coefficient(w/ m2-k)	Mass flow rate(kg/s)
0.047	$1.65e^{-03-}$	$5.16e^{-03}$	$7.26e^{+02}$	0.000875826 93

Month	Heat transfer rate(W)
January	73.4506
February	76.64165
March	82.05737
April	130.2031
May	144.85
June	144.513
July	127.2891
August	119.9395
September	121.4141
October	118.4785
November	99.03662
December	82.94922

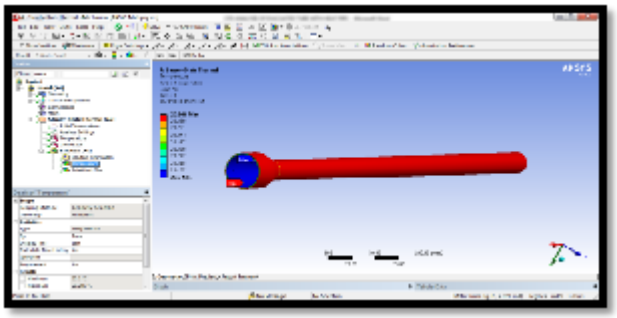
Mass flow inlet 0.167 kg/s

Mass flow inlet(kg/s)	Pressure in P(Pa)	Velocity (m/s)	Heat transfer coefficient (w/m2-k)	Mass flow rate(kg/ s)
0.167	$6.43e^{-01}$	$1.87e^{-02}$	$7.26e^{+02}$	0.0025 65

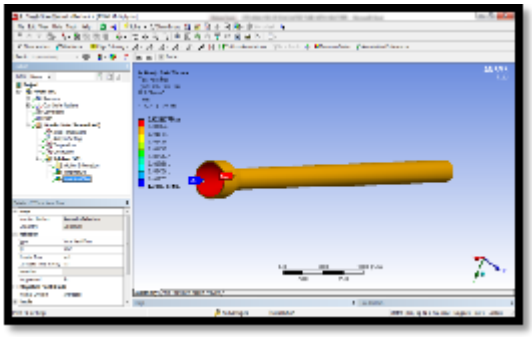
Month	Heat transfer rate(W)
January	255.94336
February	305.20313
March	375.47
April	456.98633
May	495.191433
June	494.13867
July	446.82617
August	420.75391
September	425.83789
October	415.49023
November	346.73047
December	289.75391

THERMAL ANALYSIS OF EVACUATED TUBE

CASE1: SINGLE HEAT PIPE
January month (20.2^{0}C)

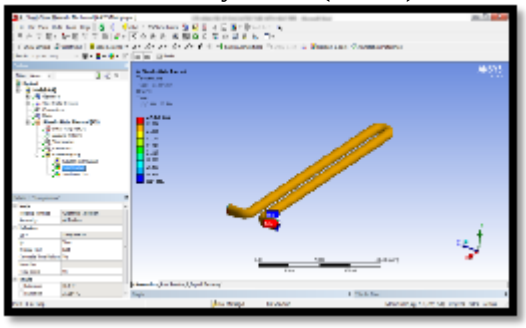


TEMPERATURE DISTRIBUTION

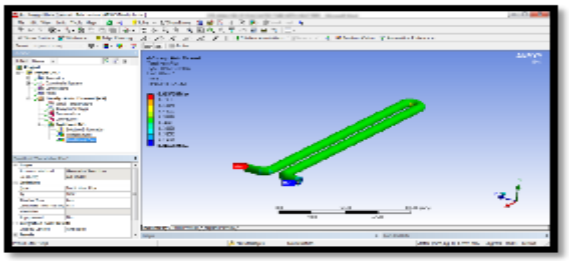


HEAT FLUX

U-Bend type heat pipe
January month (20.2^{0}C)



TEMPERATURE DISTRIBUTION



HEAT FLUX

III. CONCLUSION

In this thesis the evacuated tube collector with heat pipe modeling in creo parametric software and analysis in ANSYS software at different mass flow rate (0.047 & 0.167 kg/s) and at different temperatures of month(January to December).

CFD analysis to determine the pressure drop, velocity, mass flow rate, heat transfer coefficient and heat transfer rate for evacuated tube collector with heat pipe. Thermal analysis to determine the temperature distribution and heat flux with different temperature of month (January to December).

By observing the CFD analysis the pressure drop, velocity, mass flow rate & heat transfer rate increases by increasing the inlet flow rates. By observing the heat transfer rate more at may month temperature compare with remaining month average temperatures.

REFERENCES

1. Wang.Z, Yang. W, Qiu.F, Zhang.X, Zhao.X, Solar water heating: From theory, application, marketing and research. Renew. Sustain. Energy Rev. 2015, 41, 68–84.
2. Balusamy.T, Sadhishkumar.S, Performance improvement in solar water heating systems—A review. Renew. S Energies 2015, 8 11402
3. Islam M.R., Sumathy K., Khan. S.U, Solar water heating systems and their market trends. Renew. Sustain. Energy Rev. 2013, 17, 1–25.
4. Renewable Energy Policy Network. Renewable Energy 2010: Key Facts and Figures for Decision Makers. Global Status Report. Available online: http://www.ren21.net/gsr (accessed on 10 July 2015).
5. Kulkarni.G.N, Kedare.S.B, Bandyopadhyay.S, Determination of design space and optimization of solar water heating systems. Sol. Energy 2007, 81, 958–968.
6. Hottel.H.C, Whillier.A, Evaluation of Flat-Plate Collector Performance; University of Arizona Press: Tucson, AZ, USA, 1958.
7. Klein.S.A, Calculation of flat-plate collector utilizability. Sol. Energy 1978, 21, 393–402.
8. Klein.S.A, Beckman.W.A, Duffie.J.A, A design procedure for solar heating systems. Sol. Energy 1976, 18, 113–127.
9. Klein.S.A, Beckman. W.A, A general design method for closed-loop solar energy systems. Sol. Energy 1979, 22, 269–282.
10. Yan.C, Wang. S, Ma. Z, Shi. W, A simplified method for optimal design of solar water heating systems based on life-cycle energy analysis. Renew. Energy 2015, 74, 271–278.

AUTHORS PROFILE

Dr. Sakthivel Munirajan is currently working as Professor in the Department of Mechanical Enginnering at Koneru Lakshmaiah Education Foundation deemed to be University, Vijayawada. His area of research is solar and Energy Engineering. He has published 15 international Journals.

P Rajanikanth Reddy is perusing M-Tech. in Thermal Engineering, Department of Mechanical Enginnering at Koneru Lakshmaiah Education Foundation, Vijayawada. His area of interest is solar engineering.