International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 22 No. 4 (2026)



ijerst.editor@gmail.com

editor@ijerst.com

ISSN 2319-5991 www.ijerst.com
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Peer Reviewed, Referred & Indexed Journal

Research Paper

THERMAL PERFORMANCE ANALYSIS OF A SOLAR WATER HEATING SYSTEM WITH HEAT PIPE EVACUATED TUBE COLLECTOR

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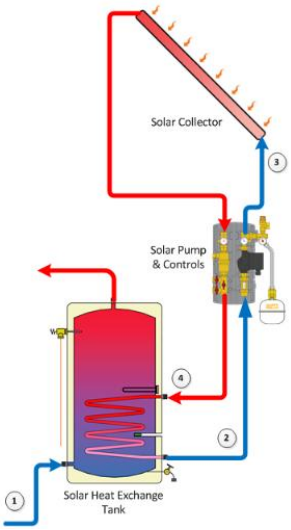
Abstract Solar water heating (SWH) is the use of a solar thermal collector to convert sunlight into heat for water heating. A sun-facing collector warms a working fluid, which is then stored for later use. A detailed assessment of the utilisation of solar energy for hot water generation utilising evacuated tube collectors and heat pipe technology has been conducted in this work. The use of solar energy in a hot water producing system using an Evacuated Tube Collector would assist to enhance energy economics, consumption, and efficiency.

The evacuated tube collector with heat pipe was modelled in Creo parametric software and analysed in ANSYS software at different mass flow rates (0.057 and 0.177 kg/s) and at varied temperatures throughout the Dayin this thesis 9am to 5 pm).For an evacuated tube collector with heat pipe, CFD analysis was used to calculate the pressure drop, velocity, mass flow rate, heat transfer coefficient, and heat transfer rate. Thermometric study to measure temperature distribution and heat flow at various temperatures throughout the Day (9am to 5 pm).

1. INTRODUCTION

Solar water heating simply means using the sun's energy to heat hot water for your home. The average person uses between 20 and 30 gallons of hot water a day. A family of 4 would use between 2,400 and 3,600 gallons of hot water every month - all of which can be provided for free, using the sun's energy. A solar water heater is sized to accommodate your family's current usage - meaning your habits and lifestyle don't have to changed. Once the solar hot water system is installed, the only thing that will change is your monthly bill.

A home solar water heater is a very simple and maintenance free way to immediately reduce your monthly energy costs. Both evacuated tube and flat plate solar hot water systems work in a similar manner.



Home Solar Water Heating System

In most residential solar hot water systems that use evacuated tubes, cold water flows into the bottom of the solar storage tank (1).

The solar loop's heat transfer fluid (usually a water & glycol mixture) is pumped up to the solar collector (2). Inside the solar collector, it is heated with the sun's energy (3). The evacuated tubes are very efficient at trapping heat from the sun and transferring it into this fluid. As the fluid moves through the solar evacuated tube collector and heated up, it is then pumped back down inside the heat exchanger in the solar tank, heating the water inside the solar tank. This is just one of the more common designs used in a home solar hot water system. Other

designs are available, and can be used depending on your specific application.

2. LITERATURE REVIEWS

M.V. Kulkarni, Dr. D. S Deshmukh (2014) [1] focused on PCM type solar water heater. The system consists of two simultaneously functioning heat-absorbing units. One of them is a solar water heater and the other a heat storage unit consisting of PCM (paraffin). The water heater functions normally and supplies hot water during the day. The storage unit stores the heat inPCMs during the day supplies hot water during the night.

Eze J. I. and Ojike O. (2012) [2] investigated the thermal efficiency of a passive solar water heater is undertaken. The solar water heater has two storage tanks and is used for cold and warm waters, respectively. Here copper pipes are placed in the spiral form only.

P.Selvakumar, Dr.P.Somasundaram (2012) [3] studied the effect of inclination of solar water heater on its thermal performance. The present study is carried out to find the temperature characteristics of the evacuated tube at tilt angles, viz. 0°, 15°, 30°, 45°, 60° and 90°. Obviously this idea of angles on the basis of application will create a greater impact on this environmental concerned world. The main reason why solar heaters are not preferred is the price and complexity. But when it is apparent that one can go on with any angles and less complexity which in turn means low pricing will increase the number of users to switch from electric water heaters to solar.

3. MODELING AND ANALYSIS

PTC's roots are firmly cemented in the realm of Computer Aided Design/Engineering (CAD/CAE) via it's Mechanical Design Software called Creo Parametric (originally Pro/Engineer). PTC now boasts a product catalog of tremendous breadth with Engineering Math, Product Lifecycle Management (PLM), Internet of Things (IoT), and even Augmented Reality (AR) solutions. PTC has now.

Digital Product Development using AR, PLM, IoT

Although founded around CAD/CAE, PTC's offering has since expanded to include an entire portfolio of digital product development applications. PTC's premiere AR program, ThingWorx Studio, requires fast, accurate 3D representations of an environment in order to correctly augment it. Windchill, the web-based PLM solution, relies on the modularity of a 3D assembly to easily create and manage variations of a product to suit customer need. Both of these separate technologies can then be brought together with the inherent IoT-like structure of the ThingWorx platform, meaning that an interactive AR training program can use the information gathered from the PLM system to properly gauge successful instruction: a true revolution in technology.

Creo

Despite this far reach, however, PTC's primary offering in CAD/CAE – its Creo family of software – is still its most matured and popular product. At its core, the Creo software suite from PTC focuses on interconnecting the modeling and prototyping phases of product development. Included are tools for concept and industrial design, simulation and analysis, and general production readiness. It links these often separated processes by providing fully featured tools as add-ons for their flagship software, Creo Parametric. While the Creo suite contains dozens of unique tools, familiarity with just a select few can greatly become a designer or engineer's best asset.

Creo Parametric

As the main hub for all Creo software, Creo Parametric is a robust modeling tool whose focus is on providing modularity and instant feedback for design changes. Its surfacing capabilities allow users to turn their 2D sketches into full 3D models by either parametrically building or organically shaping complex surfaces. CreoParametric's "Unite" toolset even features support for importing geometries from competing applications. Creo Parametric also supports 2D drafting in addition to its 3D modelling capabilities, meaning that a designer can easily switch between the 3D model and its corresponding 2D draft, with either view reflecting changes made on the other. The Creo suite's emphasis towards real, manufactured products is demonstrated by many of CreoParametric's features.

Surfacing

CreoParametric's surfacing abilities are some of its most mature. Supporting both parametric and freestyle surfacing, Creo Parametric lets a designer change every curve of a geometry by using either of these intuitive methods. With parametric surfacing, changes can be made using traditional

modelling tools, where sweeps, blends, and extensions are used to acquire precise, tightly defined dimensions. These features are ideal for a user already familiar with other modelling software, as the use of many of the same techniques will have a designer feeling at home. The parametric nature of this method allows models to be easily modified in a predictable, scalable manner.

While the parametric approach to surfacing is CreoParametric's signature feature, its newer support for freestyle surfacing gives users a fully viable alternative. Shapes can be molded like clay, meaning that a part can be shaped just from a single starting figure. This feature is best utilized alongside a 2D concept sketch, as the curves of the sketch can then be easily matched by deforming a starting model.

Sheet metal

Creo's manufacturing focus is once again exemplified with its sheetmetal design features, which allow for the creation of sheetmetal parts that are ready for manufacturing off the shelf. The sheetmetal toolset permits the user to bend and shape the metal only in ways that would be feasible in industrial manufacturing. This lets the user focus on simply designing a product, rather than worrying about how it will be manufactured.

CFD

Computational fluid dynamics or CFD is the analysis of systems involving fluid flow, heat transfer and associated phenomena such as chemical reactions by means of computer-based simulation. The technique is very powerful and spans a wide range of industrial and non-industrial application areas. Some examples are:

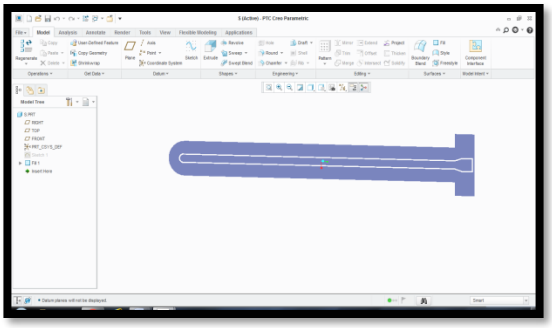
- Aerodynamics of aircraft and vehicles: lift and drag
- Hydrodynamics of ships
- Power plant: combustion in internal combustion engines and gas turbines
- Turbo machinery: flows inside rotating passages, diffusers etc.
- Electrical and electronic engineering: cooling of equipment including microcircuits
- Chemical process engineering: mixing and separation, polymer moulding
- External and internal environment of buildings: wind loading and heating/ventilation
- Marine engineering: loads on off-shore structures
- Environmental engineering: distribution of pollutants and effluents
- Hydrology and oceanography: flows in rivers, estuaries, oceans
- Meteorology: weather prediction
- Biomedical engineering:

Blood flows through arteries and veins From the 1960s onwards the aerospace industry has integrated CFD techniques into the design, R&D and manufacture of aircraft and jet engines. More recently the methods have been applied to the design of internal combustion engines, combustion chambers of gas turbines and furnaces. Furthermore, motor vehicle manufacturers now routinely predict drag forces, under-bonnet air flows and the in-car environment with CFD. Increasingly CFD is becoming a vital component in the design of industrial products and processes. The ultimate aim of developments in the CFD field is to provide a capability comparable with other CAE (computer-aided engineering) tools such as stress analysis codes. The main reason why CFD has lagged behind is the tremendous complexity of the underlying behaviour, which precludes a description of fluid flows that is at the same time economical and sufficiently complete. The availability of affordable high-performance computing hardware and the introduction of user-friendly interfaces have led to a recent upsurge of interest, and CFD has entered into the wider industrial community since the 1990s.

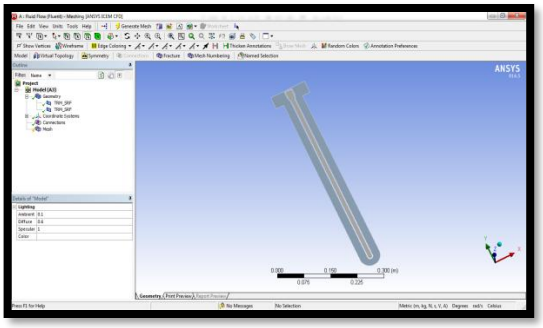
4. MODELS OF EVACUATED HEAT PIPE

Using CREO parametric software

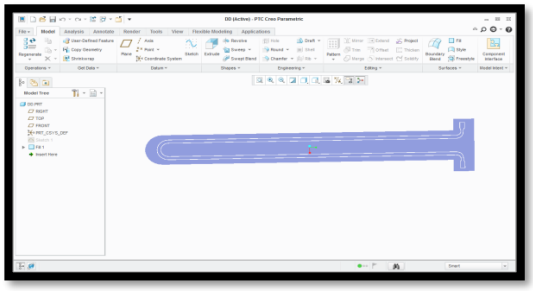
The evacuated tube with heat pipe is modeled using the given specifications and design formula from data book. The isometric view of evacuated tube with heat pipe is shown in below figure. The evacuated tube with heat pipe outer casing body profile is sketched in sketcher and then it is revolved up to 360^0 angle using revolve option and tubes are designed and assemble to in evacuated tube with heat pipe using revolve option.



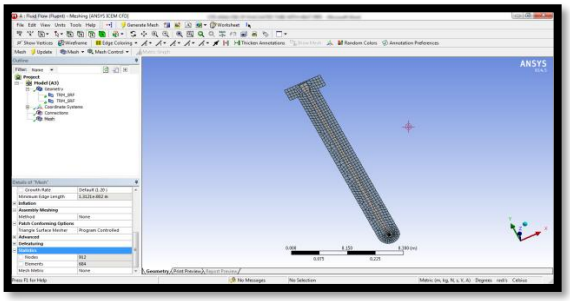
Single type heat pipe



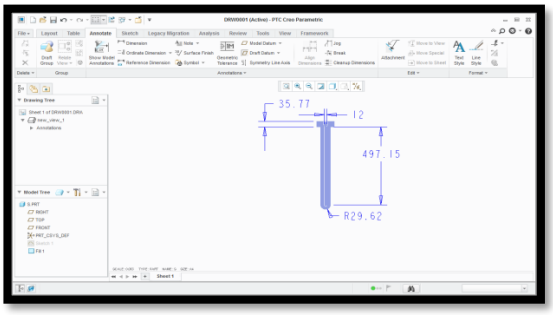
Meshed model



U-bend type heat pipe



Inlet and outlet conditions



Drafting image

CFD ANALYSIS OF EVACUATED TUBE WITH HEAT PIPE

Evacuated tube – Single heat pipe

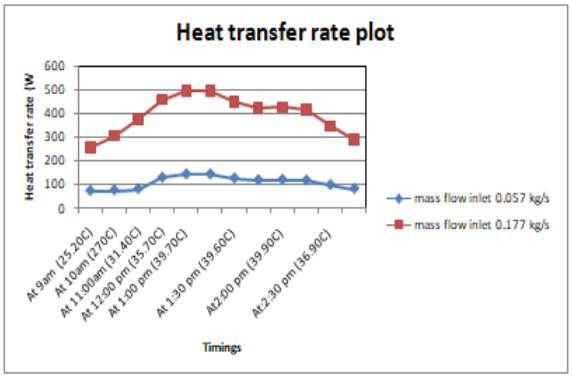
Mass flow inlet – 0.057& 0.177kg/s

Temperature - throughout the Day (9am to 5 pm).

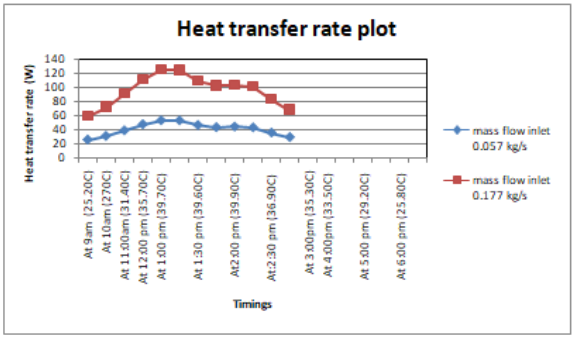
Imported model

5. RESULTS AND ANALYSIS

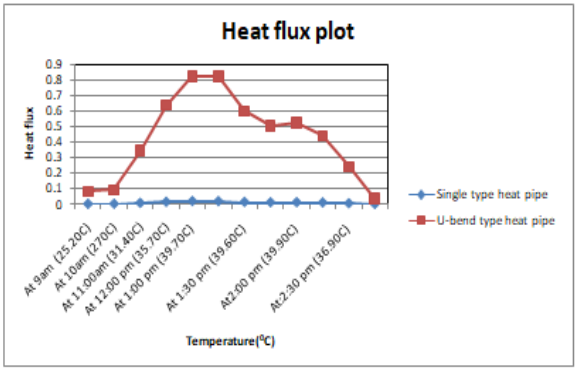
Single type heat pipe CFD analysis results



Steady State Thermal Analysis of Evacuated Tube



U-Bend type heat pipe



6. CONCLUSIONS

1. 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 (0.057 & 0.177 kg/s) and at different temperatures of Thought day(9am to 6pm).
2. 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 Thought day(9am to 6pm)..
3. By observing the CFD analysis the pressure drop, velocity, mass flow rate & heat transfer rate increases by increasing the inlet flow rates.
4. By observing the heat transfer rate more at 1:00 pm temperature compare with remaining Timings average temperatures.

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