Thermal Performance of a Solar Water Heater by Optimizing Shape of Shell in Parallel Flow and Counter Flow Conditions

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Abstract

In present investigation experimental analysis is performed in solar water heater with different mass flow rate, the observed value of exit temperature of water is compared with numerical model developed in CFD with optimization in flow pattern i.e. parallel flow and counter flow with optimizing shape of solar absorbing shell i.e. cylindrical shell in place of square shell to predict effective temperature distribution. further, In a Computational Fluid Dynamics (CFD), the trial has been conducted on the temperature, for a solar water heater with square and cylindrical shell. In the CFD investigation it was assumed that, the flow of water is parallel flow and counter flow. This investigation was carried out on a mass flow rate 0.02, 0.04, 0.06 kg/s. When the desired temperature distribution was carried with parallel flow and counter flow with cylindrical shell it was found that;

1. *The parallel flow in solar water heater has less capability of high water temperature at exit of solar water heater.*
2. *The counter flow configuration of flow pattern exhibits high amount water temperature at in solar water heater.*
3. *Whereas, in counter flow the mass flow rate of 0.04 kg /s have higher temperature distribution due to effective temperature distribution between tubes and solar radiation absorbing shell.*
4. *Thus, the cylindrical radiation absorbing shell has maximum exerts maximum temperature concentration on tube bundles of flowing water.*

Keywords— *CFD analysis, FLUENT, Solar water heater, temperature distribution, parallel flow, counter flow, solar radiation absorbing shell.*

I. Introduction

Sun water heating is a regularly-not noted source of renewable energy. A well designed Sun water machine can complement or even replace a conventional electric or fuel heater. Solar water warmers are environmentally friendly and may save a home owner a top notch deal of cash. But, the money stored through the use of a sun heater is proportional to the efficiency of that Unique device. Many exceptional types of sun water heating structures exist. The kind of system used regularly Relies upon at the purpose and region. The solar is the shining famous person of our solar device, it's miles the closest star to earth, it helps almost All life on earth via photosynthesis, and drives earth's weather and weather. It's far a gaseous Close to best sphere, which is about 330 000 times that of the Earth [2]. Nearly seventy 3% of the sun's mass includes hydrogen, the relaxation is often helium with Surprisingly small amounts of oxygen, carbon, neon and iron [3]. The sun is positioned round 150 Million km from the earth, its light takes round eight mins to arrive to us [4].

Positive displacement compressors include reciprocating compressors in its category. Larger volumes of gas are compressed and brought to a greater pressure. The most popular type of positive displacement compressors are reciprocating compressors. The only moving parts of the device are a piston and a cylinder. The pressure rises as a result of the piston's upward and downward movement inside the cylinder, which squeezes the gas into a smaller volume. A single cylinder compressing on one side of the piston is the fundamental reciprocating compression element. The two fundamental single-acting components will be used on both sides simultaneously in a single up-down movement. The crankshaft and piston rod convert the rotary motion coming from the engine or any other external driver going to the compressor into linear motion. The crankpin fastens the piston rod's end to the as the crankshaft rotates, one is reciprocated by the piston and the other by the crankshaft. The suction and discharge valves, which are essentially check valves that permit the one-way passage of the gas, are typically found at the top and bottom of the cylinder, respectively. The lower end of the cylinder will experience a partial vacuum as the piston rises; the pressure differential causes the valves to open, enabling gas to flow into the cylinder. However, for the When the cylinder's internal pressure is higher than the discharge line's internal pressure during a downward stroke, the valve will open, allowing gas to flow from the cylinder to the discharge. This is referred to as "single-acting" compression if it just affects one side of the piston, and "double-acting" compression if it affects both sides.

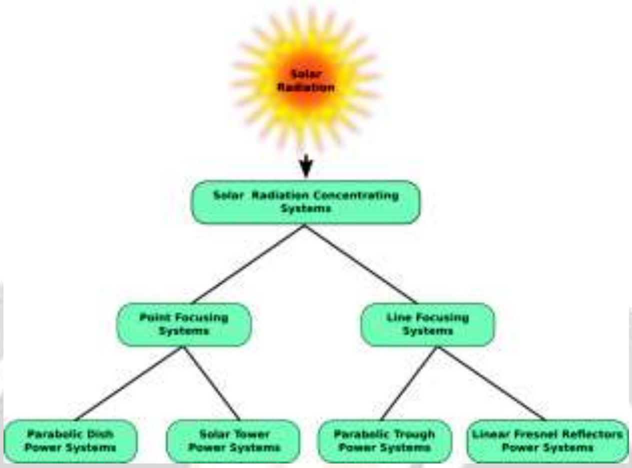
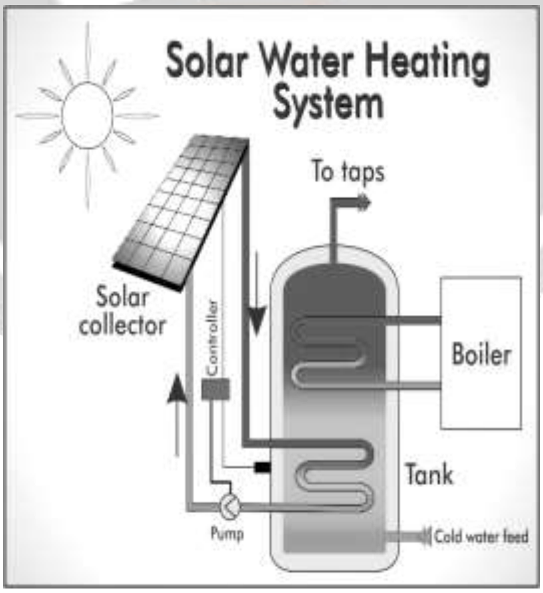


Figure1 – **Solar radiation**

II. SOLAR WATER HEATING

Sun water heating (SWH) is the conversion of daylight into warmth for water heating the usage of a Sun thermal collector [18]. This conversion of mild makes use of the previously explained power Transfer mechanisms (Radiation, conduction, convection).



Predominant components of sun water heating structures

Collector: sun thermal collectors seize and keep heat from the sun and use it to heat a Liquid.
Pump: It forces the water to circulate through the machine.
Tank: It shops the hot water coming from the sun collectors, usually the tanks are ready with insulation to lessen warmness loss.

Controller: Senses temperature differences between water leaving the solar collector and the water inside the storage tank near the warmth exchanger. The controller begins the pump whilst the water in the collector is adequately about 8 – 10 °C hotter than the water in the tank, and prevents it when the temperature difference reaches 3–5 °C. This ensures that stored water always gains heat when the pump operates and prevents the pump from excessive cycling on and off [19].

III. METHODOLOGY

The procedure for solving the problem is

- Literature survey and problem identification.
- Study of Solar water heater and related process parameters.
- Study of mathematical model related to change in temperature inside the solar water heater.
- Identification of parameters that have influence on temperature gradient and optimum values.
- Study of thermal behavior of the proposed solar water heater.
- CFD analysis of solar water heater in order to analyze the flow behavior of fluid inside the different flow pattern.
- Validation of CFD model through experimental work measured temperature of water at exit of the solar water heater.
- Study and Optimize the value of variable mass flow rate at the different types of solar water heater.
- Increase the temperature of the water at exit of solar water heater.
- Comparison of results and conclusion.
- Report preparation.

Objective

- To study input and output parameters and governing equations of solar water heater.
- To develop a CFD model assisting with fluent flow of solar water heater.
- To analyze the different mass flow rate of water (0.02 kg/s,0.04kg/s,0.06kg/s) inside the solar water heater.
- To analyze the different types of solar water heater (parallel flow, counter flow) and provide the temperature behavior of water at outlet.
- To analyze temperature profile of water using CFD approach and validation through experimental result.

IV. RESULTS

Table:1 Showing the geometric dimension of the solar water heater

Parameter	values
Heat transfer area	0.515 m
Tube numbers	8
Tube length	1
Tubes centre	0.02 m
Tube diameter	0.03 m

Table: showing the material properties of aluminium

Parameters	Values
Density kg/m^3	2719
Specific heat J/kg-K	871
Thermal conductivity w/m-K	202.4

Table:2 showing the material properties of Copper

Parameters	values

Density kg/m^3	8978
Specific heat J/kg-K	381
Thermal conductivity w/m-K	387.6

Table:3 showing the values of the temperature

Mass flow rate (kg/s)	**Temperature of water at the exit of solar water heater (K) (ANSYS)**	**Temperature of water at the exit of solar water heater (K) (Experimental)**
0.02	328.58	318.85
0.04	326.55	315.66
0.06	324.45	312.85

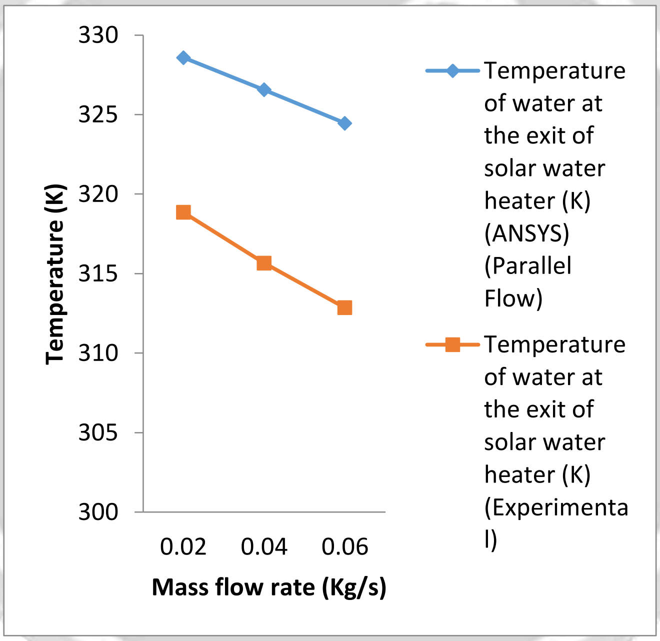


Figure 2 – Comparison of temperature in solar water heater in parallel flow.

Table:4 showing the values of temperature distribution with respect to mass flow rate.

Mass flow rate (kg/s)	**Temperature of water at the exit of solar water heater (K) (ANSYS)**	**Temperature of water at the exit of solar water heater (K) (Experimental)**
0.02	338.58	318.85
0.04	336.55	315.66
0.06	332.58	312.85

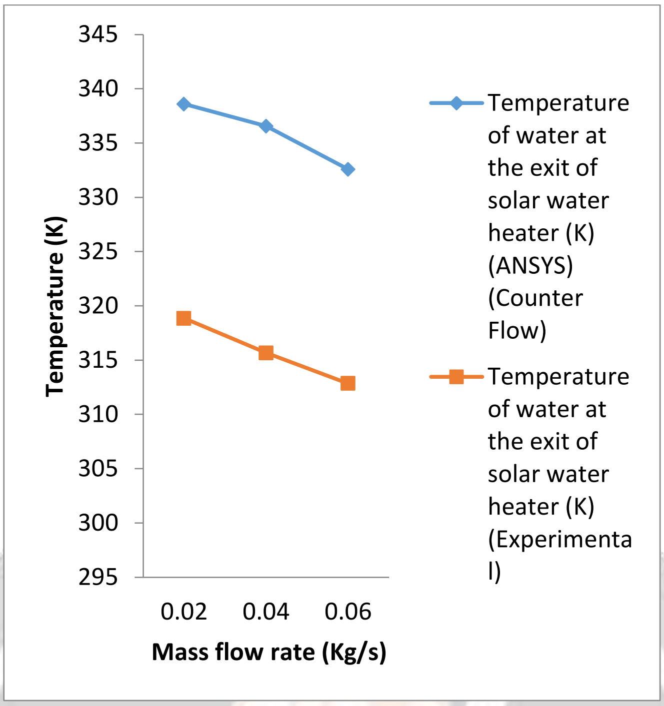


Figure 3 – Comparison of temperature in solar water heater in parallel flow.

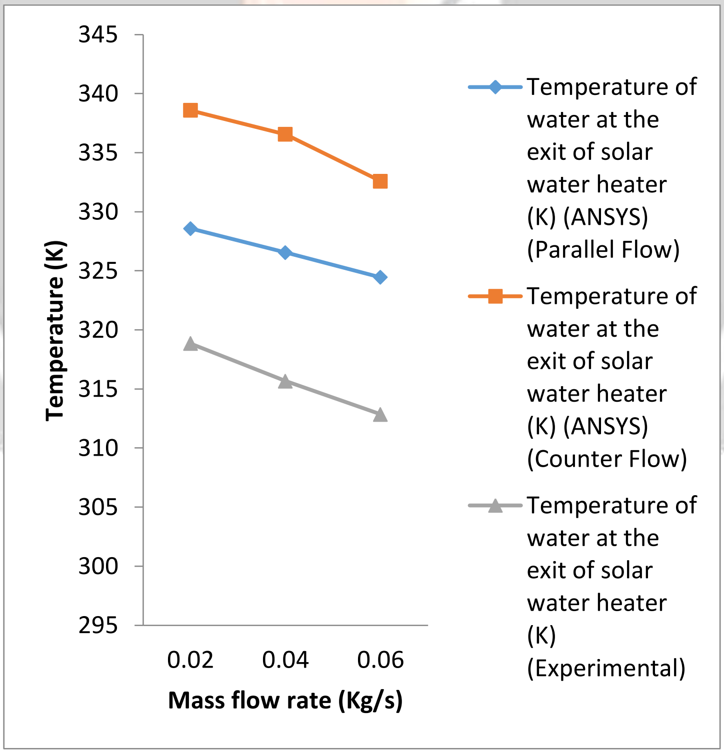


Fig. 4 – Overall comparison of temperature with mass flow rate in solar water heater.

Table:5 showing the values of temperature for circular shell of solar water heater.

Temperature of water at the exit of solar water heater (K) (Circular Shell)	Temperature of water at the exit of solar water heater (K) (Rectangular Shell)
788	598

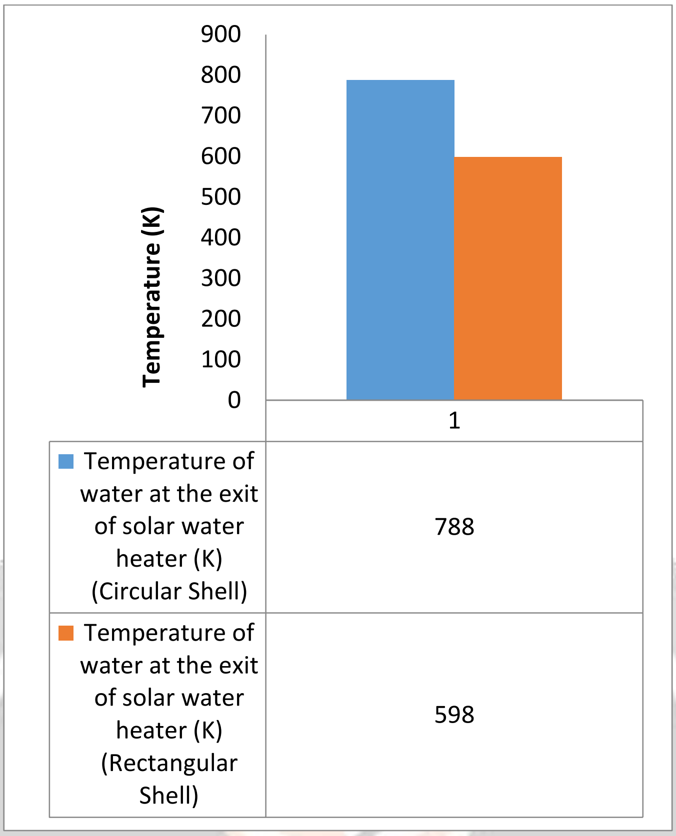


Fig. 5 –Comparison of shell temperature with mass flow rate in solar water heater.

CONCLUSIONS

- The CFD model was developed on Ansys (design modeler) and analysis was done by Fluent 16.0.
- The prediction of CFD model shows good relation with experimental result.
- Simulated the solar water heater having parallel flow and counter flow pattern for different mass flow rate of (0.02-0.06 kg/s) and found that counter flow of pattern exhibits maximum temperature at outlet.
- From the above result we have least temperature distribution for parallel flow configuration thus due to decreased convection during flow which minimizes optimum mass flow rate.
- From the above result the best temperature distribution on circular shaped shell of solar water heater is observed due to equal distribution of radiation.
- So, from the above It was concluded that the circular shaped shell of solar water heater with different mass flow rate including counter flow configuration having better temperature distribution, due to increase in surface area of shell, thus heat concentration increase in surface area of solar water heater.

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