Comparison of solar water heater performance with u curved pipes and straight pipes design using CFD

Siwan E. Perangin-angin* and Himsar Ambarita
Sustainable Energy Research Centre, Universitas Sumatera Utara, Almamater Street
Kampus USU, Medan 20155, Indonesia

*Email: edi_siwan@yahoo.com

Abstract. Solar energy has a very important role from time to time. In this era, the development of technology that uses the sun as a primary source is growing rapidly. One application of solar energy in solar water heaters. Solar Water Heater is a device that uses energy from the sun's heat to heat the fluid air flowing in the Pipe so that the temperature of the fluid that comes out of the Pipe is higher. Pipes are one of the most important parts of solar water heaters. Pipes as a medium for fluid flow and heat transfer from the collector domain to air fluid. Pipe design is an important factor in the design of solar collectors. In this research, we will discuss the performance of 2 types of pipes. The first straight pipe type and the second pipe type U Curved Pipes. With CFD simulation methods and variations in fluid flow velocity, the results of changes in fluid temperature of the fluid coming out differ from the 2 types of pipes. The increase in temperature seen in liquid air in the pipe faces 0.9425% compared to straight pipes.

1. Introduction
The need for the availability of Hot Water for bathing needs is something that cannot be released in modern times. Especially for developed cities in the world. We can see in every place, in hotels, apartments, at home and in other public places [1]. This need drives every company or researcher to develop an efficient water heating system. Also related is Indonesia which is a country that develops and enhances economic development which is able to increase development in every city in Indonesia.

In general, air heating systems in homes and other places use electricity as an energy source. And the use of Electric Heaters requires a large enough energy to heat water with a large capacity and with a certain temperature. Not just using electricity, now is starting to develop solar energy as a source of energy. And one of the applications in Solar Water Heater [2]. From the results of initial research, the use of solar energy in the Solar Water Heater can increase efficiency and reduce the use of electrical energy which reduces the cost reduction that must be paid to the electricity supplier. From the data obtained, 13-17% of residential electricity consumption in America is water heater. It can be imagined the amount of energy that can be saved from a Solar Water Heater system. But this system also has weaknesses. This system cannot work in the sun. Therefore many make a water heater system with a hybrid system or use a storage frame that makes it so the air is prepared for usage.

The working principle of the Solar Water Heater is almost the same as the working principle of the Solar Cooker or Solar Collector in general [3]. Where using solar energy to heat the collector, heat is present in the collector convection and radiation heat transfer occurs [3]. This heat transfer process is used to heat air flowing in a tube with a certain speed [4]. There are several solar collectors, there are flat plates, evacuated tubes, and parabolic trenches. collector (FPC) and evacuated tube collector (DLL) [3] are collectors most commonly used by the general public for household scale water heating applications. Factors that influence the performance of the Solar Water Heater plate are the absorber
plate [5]. In general, the type of absorbent plate used for solar water heating is a type of flat plate because it is simpler and easier to obtain.

One component that affects the performance of solar water heaters is the Pipe. The type of pipe commonly used is copper. Copper has better conduction to help absorb heat from the Complete Solar Collector, so the pipes increase the temperature of the performance of the solar water heater.

In this study will examine the meeting of a straight pipe solar water heater with a solar water heater design with leaning pipes. Conventional solar water heaters use bow water heaters to streamline the dimensions of solar water heaters [6]. This is what wants to be studied whether influencing the bow can affect the efficiency of the solar collector.

To study the simulation of performance between these 2 types of solar water heaters can be done with experimental tests as well as with simulation methods. In this study, the method chosen as an evaluation is more suitable and can be produced more accurately. The simulation uses CFD software to see changes in the Exit Temperature and Countor at each Pipe point.

2. Method
This study refers to experimental data from previous studies. The data that has been presented is then supplemented with the help of CFD software. This study compares 2 designs of Solar Water Heater with 2 types of Pipes. The first is a straight pipe and the second is a pipe with 8 bow of the same length in each type of solar water heater pipe which is 21 m.

![Figure 1. Geometry of U curved pipe.](image1)

![Figure 2. Geometry of a straight pipe.](image2)
For the entered boundary conditions obtained from previous experimental data. The pipe is considered to have a heat transfer by convection of 176.48 W/m²-K, a Collector Temperature of 65°C and a pipe inlet velocity of 0.4 m/s.

\[ \rho \left( \frac{\partial u_x}{\partial x} + \frac{\partial u_y}{\partial y} + \frac{\partial u_z}{\partial z} \right) = 0 \]  

2.1. Simulation

3D simulation on Steady State conditions. For turbulent flow, turbulence models are the standard k-\( \varepsilon \). The velocity and pressure fields in the collector are determined using the law of conservation of mass and momentum. For laminar flow, the continuity equation is defined by:

For the x-component:

\[ u_x \frac{\partial u_x}{\partial x} + u_y \frac{\partial u_x}{\partial y} + u_{yz} \frac{\partial u_x}{\partial z} = -\frac{1}{\rho} \frac{\partial p}{\partial x} + \mu \left( \frac{\partial^2 u_x}{\partial x^2} + \frac{\partial^2 u_x}{\partial y^2} \right) \]  

For the y-component:

\[ u_x \frac{\partial u_y}{\partial x} + u_y \frac{\partial u_y}{\partial y} + u_{yx} \frac{\partial u_y}{\partial z} = g y \beta (T - T_\infty) + \mu \left( \frac{\partial^2 u_y}{\partial x^2} + \frac{\partial^2 u_y}{\partial y^2} \right) \]  

For the z-component:

\[ u_x \frac{\partial u_z}{\partial x} + u_y \frac{\partial u_z}{\partial y} + u_{yz} \frac{\partial u_z}{\partial z} = -\frac{1}{\rho} \frac{\partial p}{\partial z} + \mu \left( \frac{\partial^2 u_z}{\partial x^2} + \frac{\partial^2 u_z}{\partial y^2} \right) \]  

This model is suitable for turbulence flow studies and is already commonly used for a variety of practical engineering flows because of reasonable accuracy for various turbulent flows. The standard equation k-\( \varepsilon \) is defined as

\[ \frac{\partial}{\partial x_i} \left( \rho k \right) = \frac{\partial}{\partial x_j} \left( \mu \frac{\partial k}{\partial x_j} \right) + \frac{\partial}{\partial x_i} \left( \frac{\partial k}{\partial x_j} \right) + \frac{\partial}{\partial x_i} \left( \frac{\partial \varepsilon}{\partial x_j} \right) \]  

\[ \frac{\partial}{\partial x_i} \left( \rho \varepsilon \right) = \frac{\partial}{\partial x_j} \left( \mu \frac{\partial \varepsilon}{\partial x_j} \right) + \frac{\partial}{\partial x_i} \left( \frac{\partial \varepsilon}{\partial x_j} \right) \]
3. Result

3.1. Temperature distribution

Figure 4. Contour temperature distribution of U curved pipe (a), contour of straight pipe temperature distribution (b).

From the contour of the 2 pipes in Figure 3.1 we can see the pattern of temperature changes from the inlet pipe. From the simulation results we can see the difference in temperature of the two types of pipes. and the difference is 0.396 0C. seen in table 3.1

| Type of Solar Collector | T in (0C) | T out (0C) |
|------------------------|----------|-----------|
| U Curved Pipe          | 27.5     | 42.396192 |
| straight pipe          | 27.5     | 42.03321  |

3.2. Comparison of temperature contours at each intersection

The cut points are taken as many as 5 cut points at a distance of 100 cm, 510 cm, 920 cm, 11330 cm and 1765 cm.

a. Distance of 100 cm Speed of 0.4 m/s

Figure 5. Distance contour temperature of 100 cm from the outlet of U curved pipe (a), straight pipe (b).
b. Distance of 510 cm Speed of 0.4 m/s

![Distance contour temperature of 510 cm from the outlet of U curved pipe (a), straight pipe (b).](image)

**Figure 6.** Distance contour temperature of 510 cm from the outlet of U curved pipe (a), straight pipe (b).

c. Distance of 920 cm Speed of 0.4 m/s

![Distance contour temperature of 920 cm from the outlet of U curved pipe (a), straight pipe (b).](image)

**Figure 7.** Distance contour temperature of 920 cm from the outlet of U curved pipe (a), straight pipe (b).

d. Distance of 1330 cm Speed of 0.4 m/s

![Distance contour temperature of 1330 cm from the outlet of U curved pipe (a). straight pipe (b)](image)

**Figure 8.** Distance contour temperature of 1330 cm from the outlet of U curved pipe (a). straight pipe (b)
e. Distance of 1765 cm Speed of 0.4 m/s

![Distance contour temperature of 1330 cm from the outlet of U curved pipe (a), straight pipe (b).](image)

**Figure 9.** Distance contour temperature of 1330 cm from the outlet of U curved pipe (a), straight pipe (b).

4. Conclusion

From the results of simulations of 2 types of Solar Water Heater Pipes, an increase in the temperature of fluid flow in the U Type Curved Pipe Solar Water Heaters compared with Solar Pipe Water Heater Straight type is 0.9425%, means that at each cutting point the distances are 100 cm, 510 cm, 920 cm, 1330 cm and 1765 cm.

Reference

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