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PERFORMANCE EVALUATION OF FLUID FLOW IN A STRAIGHT PIPE OF HEAT EXCHANGER

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ABSTRACT

Heat exchanger is an important device in all thermal systems. It is widely used equipment in numerous industries such as process control, petroleum refining, chemical industry, heat recovery systems and much more. Energy and material saving considerations as well as environmental challenges in the industry nowadays have stimulated the demand for high efficiency of the heat exchanger. To improve the efficiency of the heat exchanger, heat transfer performance enhancement in the heat exchanger must be considered. This study is carried out to investigate and examine the fluid flow in a straight pipe heat exchanger with thermal designing and analysed by using SolidWorks software. Three different materials of the heat exchanger are used which are copper, stainless steel and brass to identify the best material of a straight pipe heat exchanger. The heat exchanger is set to be oil-water heat exchanger model. The fluid flow properties in the pipe of heat exchanger are simulated with computerized simulation to recognize the best material of heat exchanger. There are two parameters that take into consideration in this study, which are temperature and pressure distributions. Through the simulation results, copper shows the most efficient heat transfer compared to stainless steel and brass. This implies that, copper is the most efficient heat conducting and it can be concluded that the effects of different material and fluid flow in the pipe and in the cylinder of a straight pipe heat exchanger definitely able to enhance the performance of the heat exchanger. The analysis of the findings of this study is presented in this paper.

Keywords: fluid flow, straight pipe, thermal systems, oil-water heat exchanger.

INTRODUCTION

The heat exchanger is an important device in various thermal systems, for example condenser and evaporation in a refrigerant system, boiler and condenser in steam power plants and etc. It is used to transfer the heat from the hot fluid to cold fluid with maximum rate and minimum investment. The heat exchanger is widely used in industrial applications such as process industries, chemical industries, food industries and etc. Vitality and material sparing contemplations and natural difficulties in the business have re-enacted the interest for high productivity of heat exchanger. Continuous improvement of heat exchanger empowers the span of heat exchanger to be significantly diminished. A higher rate of heat exchange with low space prerequisite is needed for minimizing warmth exchanger.

Nowadays, there are several types of heat exchanger had been introduced, for example plate heat exchanger, plate and shell heat exchanger, plate fin heat exchanger, double pipe heat exchanger, shell and tube heat exchanger and straight tube heat exchanger. However, this study is focused on a straight pipe heat exchanger. The straight pipe heat exchanger is one type of heat exchanger which is designed with simple straight tube. It is commonly found in steam generator at the power plant. In other word, it is a sub of shell and tube heat exchanger type. This straight tube was made in the shell with baffle. Figure-1 shows an example of a straight pipe heat exchanger.

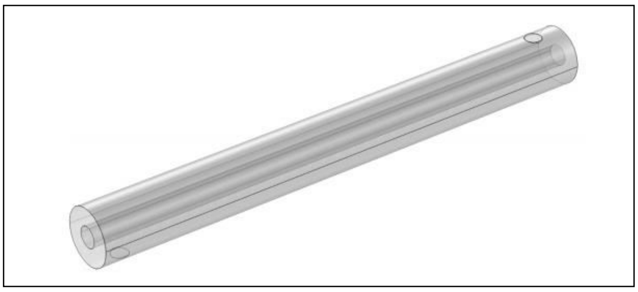

Figure-1. Example of a straight pipe heat exchanger with inner pipe.

PRINCIPLE OF HEAT EXCHANGER

The transfer of heat between same or different two or more fluids is the basic principle of heat exchanger. Two fluids are brought in close contact with each other, but are prevented from mixing by a physical barrier. The scientific physical fluid is separated by heat transfer surface, which is transferred from the hot to cold agent (Nawras, 2014). The temperatures of the two fluids soon come to an equilibrium temperature (Agarwal *et al.*, 2014). The energy from each fluid is exchanged and no extra heat is added or removes (Raskovic *et al.*, 2010). It is known that the heat transfer capacity and cost of a waste heat recovery system is directly related to its size and thermal performance (Soylemez, 2008). Appropriately, the heat exchanger must be designed in a way that it is suited for all cases of heat exchange since the heat in the process and the heat amount of the fluids are not constant. The procedure for optimal heat exchanger design includes estimation of the exchanger heat transfer area based on the required duty and other design specifications (Caputo *et*

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al., 2008). Proper study of various technical and economical parameters such as life of heat exchanger, heat capacities and variation of temperatures of fluid under observation is required to make sure the heat exchanger performance is best suited for all (D'Addio *et al.*, 2013). Furthermore, process requirements are also important for choosing the best heat exchanger for instance pressure of fluids, pressure drop across the exchanger, heat transfer rate and the type of fluids being processed (Ismail *et al.,* 2010). Heat exchangers find a variety of applications in various industries. Thus, the limitations in each industry are different and accordingly to each modification are made in the design of the heat exchanger. There are several factors that influence the heat exchanger to increase the heat exchanger performance. For example, width of the material of the tubes, temperature variation between two fluids, thermal conductivity of the material of fabrication, physical features of the exchanger and surface area of the tubes, type of flow, i.e. counters current or co-current or mixed flow and also the properties of the liquid i.e. viscosity and the heat capacity (Agarwal *et al*., 2014). The main concern of this study is actually to access and study the fluid behaviour in a straight pipe heat exchanger by using SolidWorks. Two types of fluids which are water and oil is analysed to determine which one of these two fluids show a better flow in the heat exchanger. In addition, the heat exchanger model used three different materials which are copper, stainless steel and brass to identify the best material of a straight pipe of heat exchanger.

DESIGN AND GEOMETRY

This study performed a complete drawing, including straight cylinder pipe, inlet pipe, outlet pipe and ten tube bundles inside the straight cylinder pipe. These tubes are in a normal triangular array. It also consists of inlet and outlet pipe. The outer diameter of the cylinder is 128mm and the inner diameter of the cylinder is 125mm. The cylinder has a 3mm thickness. The length of this cylinder is same with the tube inside which is 1000mm. For the inlet and outlet pipe, the dimension is the same which 30mm for the outer diameter and the inner diameter is 20mm. The height of the cylinder is 30mm. Consequently, this inlet and outlet pipe has 10mm thickness. The complete idealized model is shown in Figure-2.

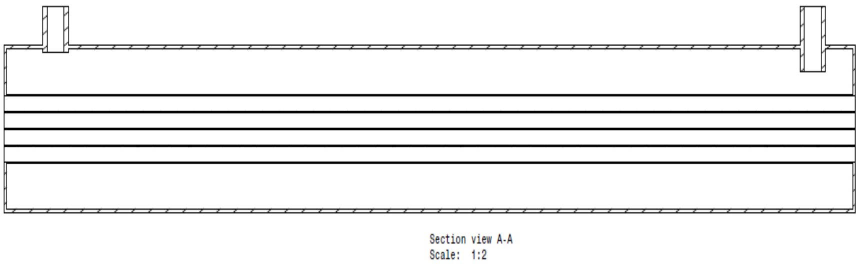

Figure-2. Side view (cut) of a straight pipe heat exchanger.

RESULTS AND ANALYSIS

This model of heat exchanger (oil-water) used two different types of fluid which are water and oil (olive oil). Water becomes a cooling agent for oil. The high temperature of the oil will pass through the tube inside the cylinder pipe and water will flow through into the cylinder pipe. The temperature of the oil is set to be 135 °C and in the inlet of the cylinder pipe the initial temperature is set to be 30 °C to cool down the oil temperature. The initial velocity of the inlet tube is customized at 5mm/s while the initial velocity of the cylinder inlet is 50mm/s. Both of the inlet tube and cylinder uses environment pressure, which is 0.101325 MPa. This model considered three different types of material which are copper, stainless steel and brass as mentioned earlier. Figures 3, 4 and 5 shows the temperature distributions of copper, stainless steel and brass in streamline, respectively.

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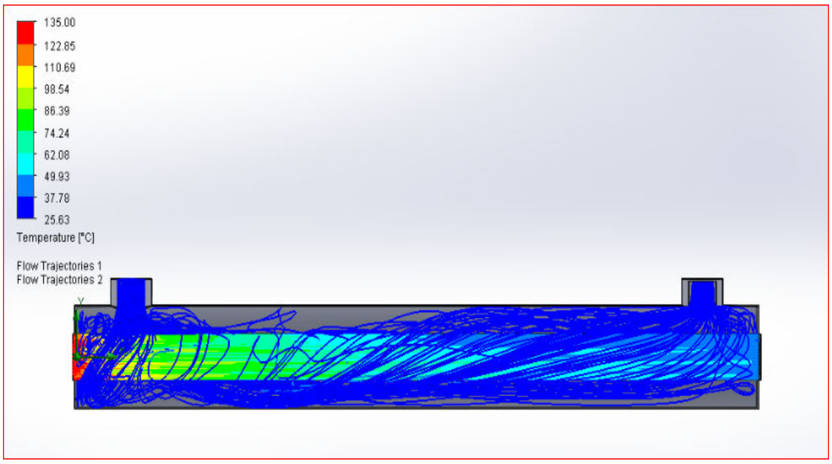

Figure-3. Temperature distributions of copper in streamline.

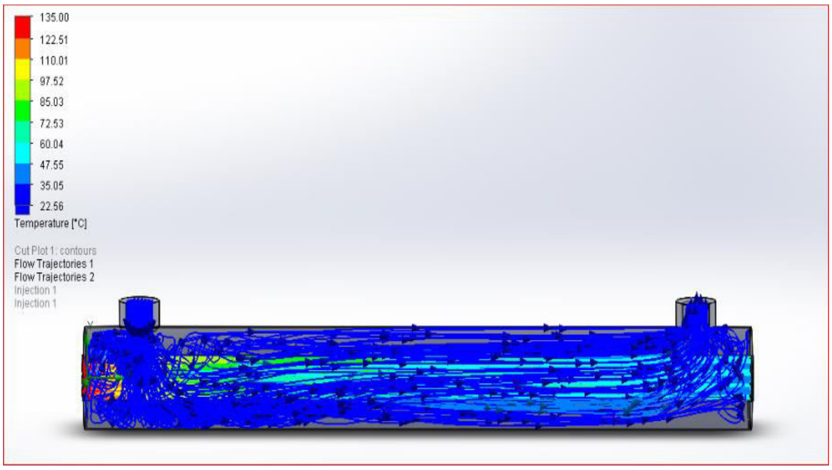

Figure-4. Temperature distributions of stainless steel in streamline.

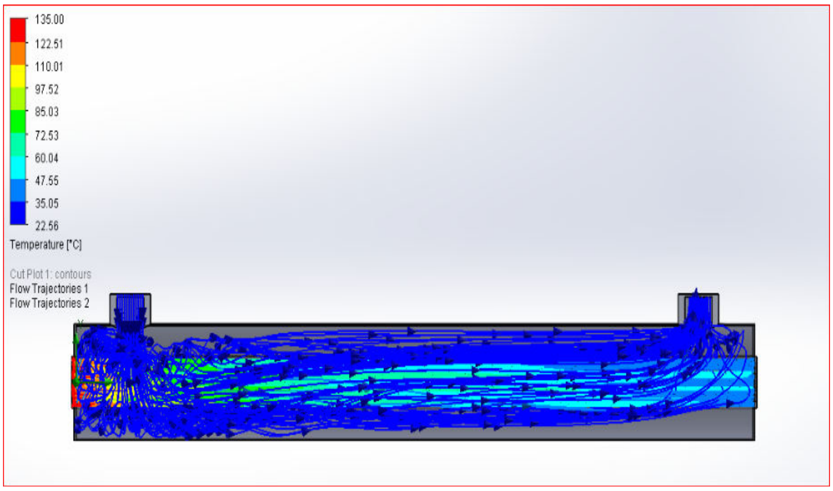

Figure-5. Temperature distributions of brass in streamline.

Figure-3 shows the highest temperature of copper is measured above 101 ^{o}C. The lowest temperature is defined at the last point which is above 49 ^{o}C. For the temperature distribution inside the cylinder pipe, the highest temperature is recorded at the second last point which is 900mm from initial inlet. The temperature measured is above 36 ^{o}C. As for the lowest temperature, the point is recorded at the first point which is 50mm from initial inlet and temperature measured is above 31 ^{o}C. Figure-4 indicates the highest temperature of stainless steel is recorded above 110 ^{o}C. The lowest temperature is defined above 50 ^{o}C. For the temperature value of fluid flow inside the cylinder pipe, the highest temperature is recorded at the second last point which is 900mm from

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initial inlet. The temperature measured is above 35 °C. The lowest temperature, the point is recorded at the second point which is above 30 °C. Meanwhile Figure-5 illustrates the fluid flow in the tube inside the cylinder and the highest temperature is recorded at the first point which is above 116 °C. The lowest temperature is measured above 56 °C. For the temperature of fluid flow inside the cylinder pipe, the highest temperature measured is above 50.8 °C and the lowest is recorded at the last point which is about 36 °C.

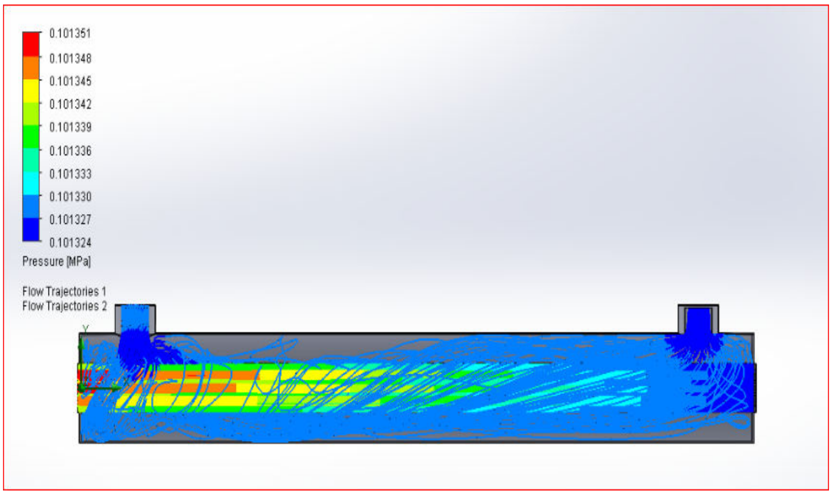

Figure-6. Pressure distributions of copper in streamline.

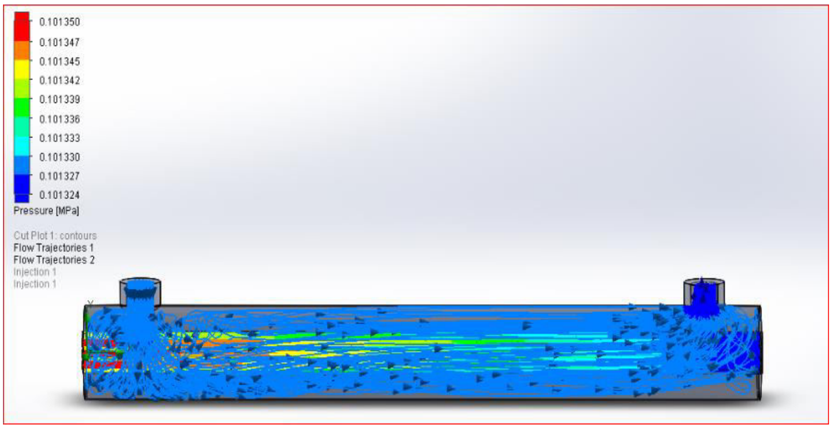

Figure-7. Pressure distributions of stainless steel in streamline.

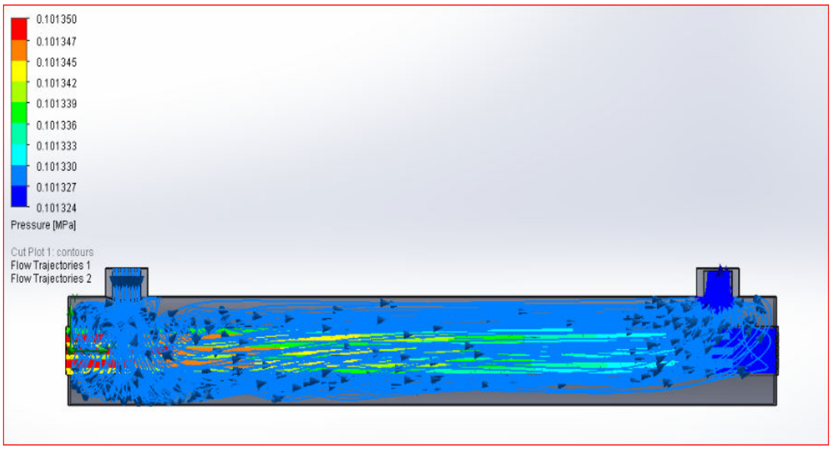

Figure-8. Pressure distributions of brass in streamline.

Figures 6,7 and 8 show the pressure distribution along the straight pipe of the heat exchanger of copper, stainless steel and brass material. The initial pressure is set to be environment pressure. So, the result obtained from

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this model has no major differences between points to points. Details of the value of pressure distributions recorded are tabulated in Tables 1, 2 and 3.

Table-1. Value of pressure and temperature distribution of copper material.

Length (mm)	**Pressure**(MPa)	**Temperature**(°C)
50	0.101342119	111.6889728
200	0.101340746	87.89074389
400	0.101337836	70.21155516
600	0.101334187	59.65320832
800	0.101330014	54.18994733
950	0.101327725	49.21434734

Table-2. Value of pressure and temperature distribution of stainless steel material.

Length (mm)	**Pressure** (MPa)	**Temperature**(°C)
50	0.101341641	110.8577131
200	0.101339507	85.47820976
400	0.101336496	69.74363096
600	0.101333312	62.69244132
800	0.101329705	57.59999568
950	0.101326339	50.8273419

Table-3. Value of pressure and temperature distribution of brass material.

Length (mm)	**Pressure** (MPa)	**Temperature** (°C)
50	0.10134588	116.1754815
200	0.101342592	108.0138382
400	0.101338209	91.09029886
600	0.101333825	72.78065057
800	0.101329441	63.39520004
950	0.101326154	56.70405333

CONCLUSIONS

The aim of this study is to analyse fluid conditions as well as to investigate the flow pattern in a straight pipe heat exchanger. From the present investigation, it can be concluded that copper showed its efficiency as heat conducting material compared to stainless steel and brass. The oil-water model shows a positive result of the copper as the best material overall. In summary, this research is considered reliable because the temperature change in the heat exchanger model is contented. However, this model can be improved in the future to get a better result in its performance. The design of heat exchanger is the key to provide a heat exchange system to work proficiently as expected. The result is used to optimize and improving heat recovery systems of the increasing demand for energy efficiency in industry. Last but not least, it is important to understand that this study is only a baseline study and as such the study should be extended for continuous improvement.

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