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CFD Analysis on Double Pipe Copper and Aluminium Heat Exchanger by Changing Boundary Conditions

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ABSTRACT

Thermal energy can be transferred from one body to other by Heat Transfer. It is the most important parameter to measure the effectiveness of the double pipe heat exchanger. The area of application is in Food industry, Beverage industry, and Bio-process industry.

. The purpose of this study is to use CFD software to analyse the effectiveness of double pipe heat exchanger by varying different inlet conditions like Temperature and Flow rate as a function of both inlet velocity and temperature variations and changing heat exchanger tube using material properties like copper and aluminum.

In this experiment, heat transfer from hot fluid to cold fluid by Double pipe heat exchanger is experimentally investigated by using different organic fluids like Benzene, Glycol, Transformer oil, Acetone and Water to get better heat transfer, the same thing is validated in CFD analysis. The experiment is performed at Laminar flow and Turbulent flow under different flow arrangements like Parallel flow and Counter flow. Same flow variations are validated in CFD analysis.

The experiment is carried out by introducing baffle segmental above the inner tube at different angular orientations i.e., 0º, 45º, 90º and 135º performed in both laminar flow and turbulent flow to get better heat transfer rate.

The study is heat transfer coefficient of Double pipe heat exchanger under various working fluids with different operating conditions, it is predicted that Counter flow exhibits better heat transfer than Parallel flow.

I. INTRODUCTION

The heat exchanger is a device which exchanges heat from higher temperature body to lower temperature body. There are many types of heat exchanger that used based on the application. For example, double pipe heat exchanger is used in chemical process like condensing the vapor to the liquid. To construct this type of heat exchanger, the size of material that want to uses must be considered since it affected the overall heat transfer coefficient. For this type of heat exchanger, the outlet temperature for both hot and cold fluids that produced is estimated by using the best design of this type of heat exchanger.

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The double pipe heat exchanger is used in industry such as condenser for chemical process and cooling fluid process. This double pipe heat exchanger is designed in a large size for large application in industry. For this research, the small heat exchanger of double pipe type is constructed which wants to make it practicality in daily life such in cooling the hot air from engine bay into intake manifold of car[7]. To make this small double pipe heat exchanger type become practicality, the best design for this small double pipe heat exchanger is choose. The objectives of this research are as follows: i. To study about heat transfer analysis in heat exchanger. ii. To design the heat exchanger based on TEMA specification The most popular are those of recuperative type. The fluids are physically separated by heat transfer surface and the heat is transferred from hot to cold agent [4]

1.1 Classification

According To Transfer Processes Heat exchangers are classified according to transfer processes into indirect- and direct contact types.

1. **Indirect-Contact Heat Exchanger**
   1.1 Storage Type Exchangers
2. **Direct-Contact Heat Exchangers**
   2.1 Immiscible Fluid Exchangers
   2.2 Gas–Liquid Exchangers
   2.3 Liquid–Vapour Exchangers

2. OBJECTIVES:

1. Log Mean Temperature Difference calculations.
2. Heat Exchanger Effectiveness (ε) calculations.
3. Pressure drop & Friction factor.
4. Overall Heat transfer co-efficient.
5. Laminar Flow in paralleled Flow Heat Exchanger calculations.
6. Laminar Flow in countered Flow Heat Exchanger calculations.
7. Turbulent Flow in a paralleled Flow Heat Exchanger with copper material calculations.
8. Turbulent Flow in a countered Flow Heat Exchanger with aluminum material calculations.
9. Turbulent Flow in a Baffle segmental inserted above the surface of the inner tube.

3 LITERATURE REVIEW

- In this Literature Survey concentrate the importance of heat exchanger where we can utilize. From the below Literature survey we can conclude that the experimental analysis carried out on Shell and tube heat exchanger, Spiral tube heat exchanger and Helical by inserting helical coils and strips using the Nano fluids like Tio_2-water and Ethylene glycol-water at composition of 40% - 60% respectively. It mainly focused on the importance and applications of CFD. Finally concluded that Spiral tube heat exchanger is 15-20% cost saving than Shell and tube heat exchanger and it gives better heat transfer.
- Muhammad Mahmoud Salam Butta, Nasir Hayat et.al, "CFD Applications in Various Heat Exchangers Design." A Review, Department of Mechanical Engineering, University of Engineering & Technology. CFD provides cost effective alternative, speedy solution and eliminate the need of prototype.
- J.S.Jayakumar, "Helically Coiled Heat Exchangers." 2008, Chemical Engineering

Research and Design. The study showed that during the design of a double pipe helical heat exchanger, the design of the outer pipe should get the highest priority to get highest overall heat transfer .

4. METHODOLOGY AND APPROACH

- Heat transfer is the most important parameter to be measured as the performance and efficiency of the double pipe heat exchanger. By using CFD simulation software, it can reduce the time and operation cost compared to experimental calculations, in order to measure the optimum parameter and the behavior of this type of heat exchanger.
- The experimental investigation is carried by varying the different flow arrangements i.e. turbulent flow, laminar flow which are further investigated through parallel and counter flow using different organic fluids like glycerin, glycol, acetone, benzene, and transformer oil, water keeping water as base fluid and by varying only hot fluids. The conditions like mass flow rate are varied at entrance of pipe and maintained at a constant temperature i.e. at inner inlet 312°K and at outer inlet 300°K, the mass flow rates in laminar flow for inner inlet & outer inlet is taken as 0.0133, 0.0166, 0.02 kg/s and 0.01, 0.0133, 0.0166 kg/s similarly in turbulent flow the mass flow rates for inner inlet & outer inlet are taken as 1.2, 1.8, 2.4 kg/s & 1.166, 1.66 & 2.166 kg/s.
- The Physical parameters like Materials properties and baffle segmental were introduced into the double pipe heat exchanger fluent model as the properties cannot be varied in experimental setup heat exchanger.
- Materials like copper and aluminum were opted for analyzing the heat exchanger. The baffle segmental are introduced to the heat exchanger on the surface of inner pipe at different angular orientations i.e. 0°, 45°, 90° and 135° to predict that at which angular orientation better pressure drop, and heat transfer co-efficient are building up.

4.1 Fluid Properties

FLUIDS	DENSITY (Kg/m^3)	VISCOSITY (Ns/m^2)	SP.HEAT (Kj/kgk)	THERMAL CONDUCTIVITY (W/mk)
ACETONE	791	0.00033	2160	0.180
BENZENE	876.5	0.00058	1821	0.167
GLYCERIN	1261	0.799	2813	0.285
GLYCOL	1116	0.0157	2200	0.258
WATER	998.2	0.001003	4174	0.6

4.2 Material Properties

Different properties of material	Density (ρ) kg/m^3	Thermal conductivity (K) W/mk	Specific heat C_P j/kgK
Copper	8954	385	383
Aluminum	2707	205	896

4.3 Experimental setup

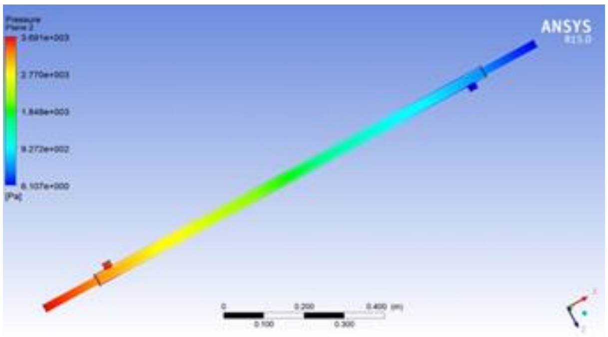
Double pipe heat exchanger

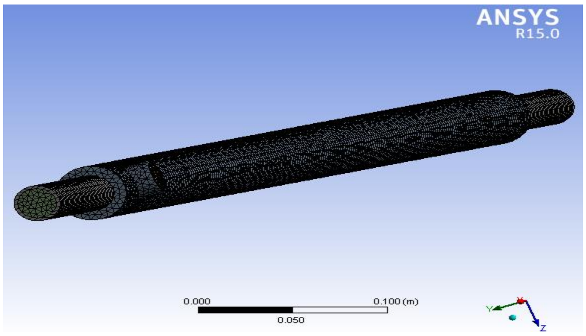
4.4 Geometry Modeling

The geometry made CATIA and imported to ANSYS fluent. The geometry consist of a length of 1.4m. Double pipe of inner tube inner diameter 0.021m and outer tube inner diameter 0.025m.

Geometry model

ANSYS15 workbench Mesh model



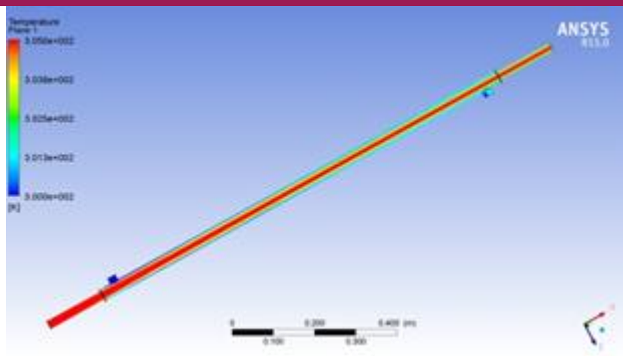


5. RESULTS AND DISCUSSIONS

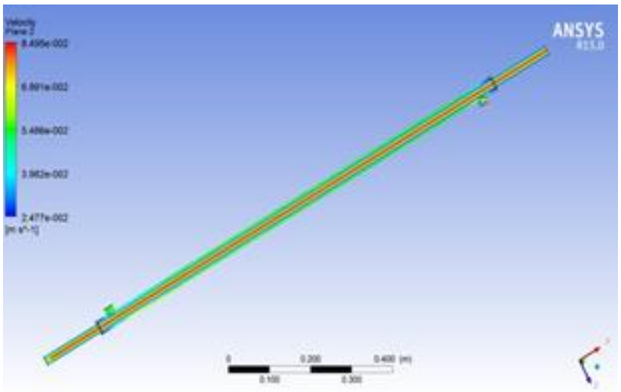
5.1 Flow variation in General Double Pipe Heat Exchanger

5.1. 1 Temperature, pressure & Velocity Profile in parallel flow

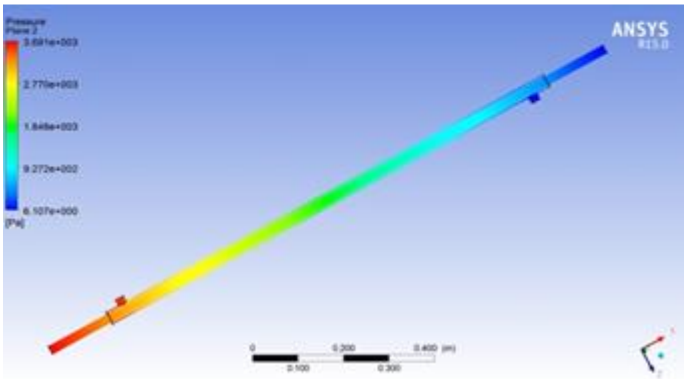
At mass flow rate 0.02m/s



Temperature variation



Velocity variation



Pressure variation

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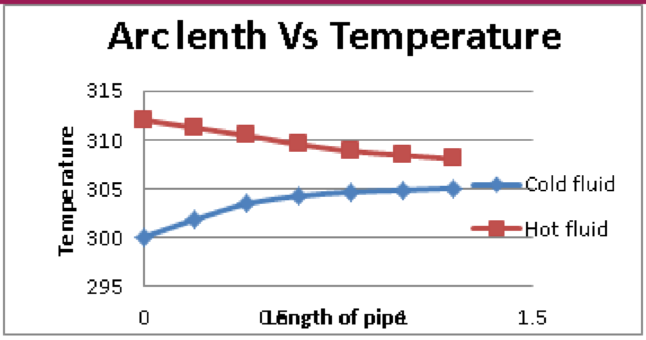
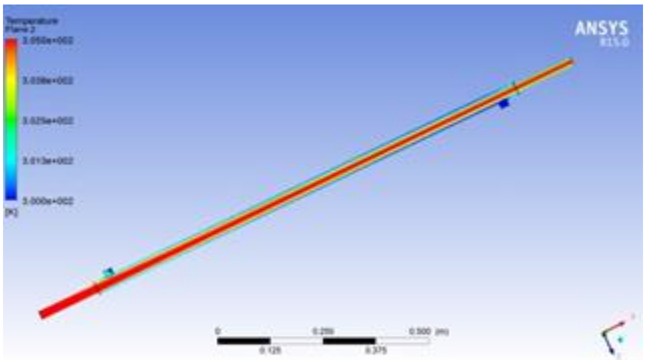


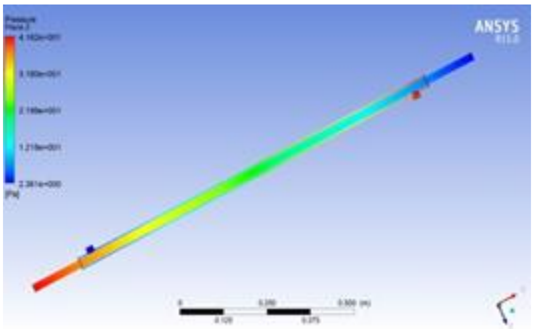
Parallel Flow profile curve

5.1.2 Temperature, pressure & Velocity Profile for counter flow Heat Exchanger

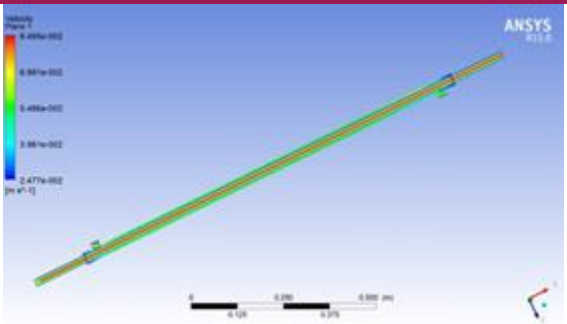
Mass flow rate 0.02



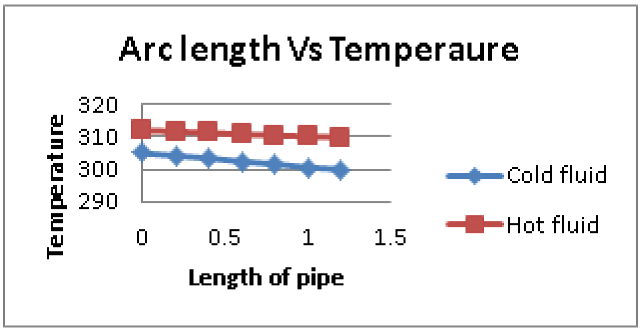
Temperature variation



Pressure variation



Velocity variation

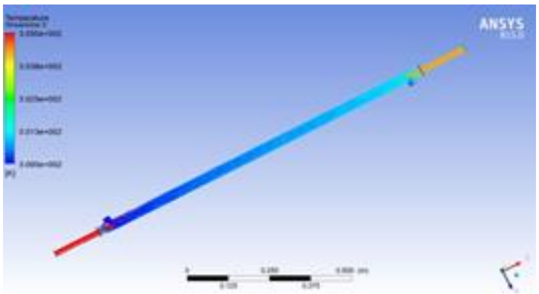


Counter Flow profile curve

5.2 Turbulent flow for copper material

5.2.1 Temperature, pressure & Velocity Profiles for parallel flow Heat Exchanger

At mass flow rate 1.2



Temperature variation

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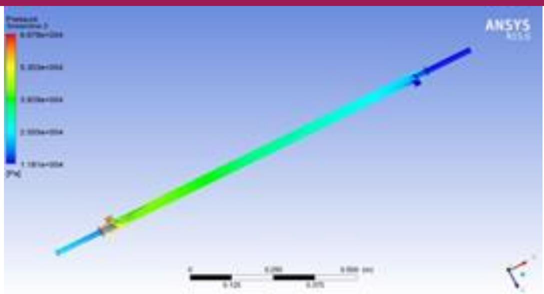
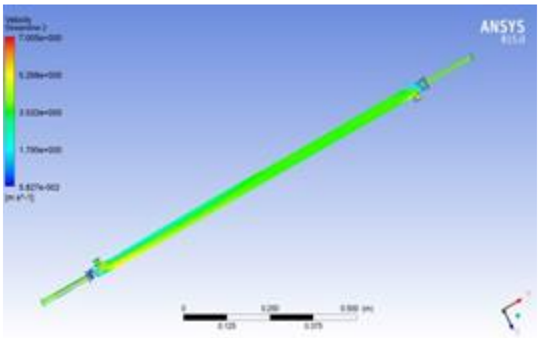
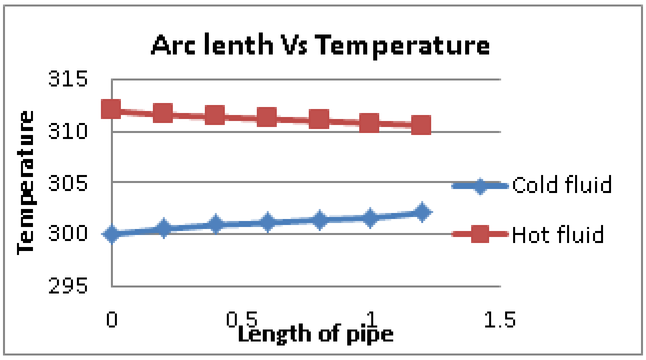


Pressure variation

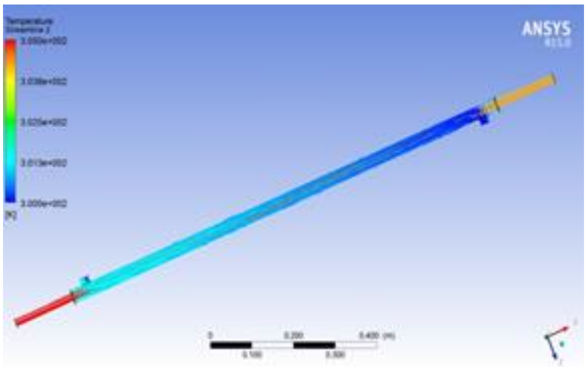


Velocity variation

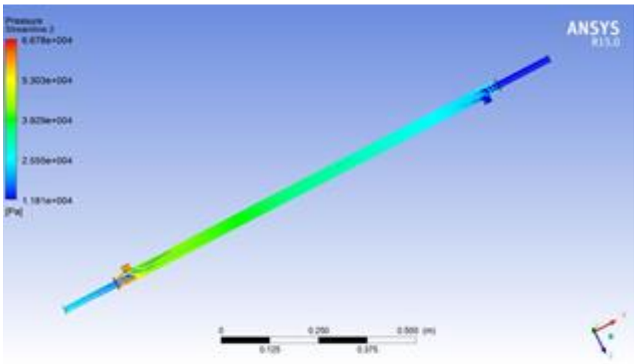


Parallel Flow profile curve

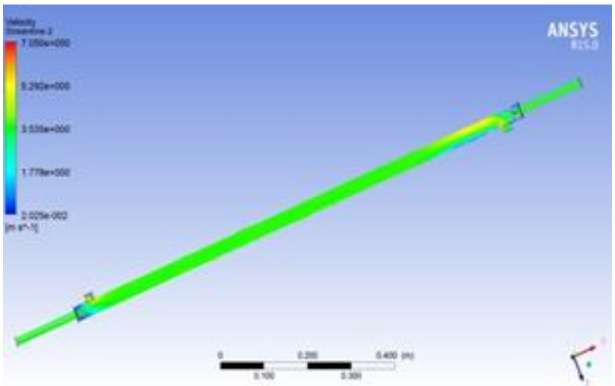
5.2.2 Temperature, pressure & Velocity Profiles for counter flow at mass flow rate 1.2



Temperature variation



Pressure variation



Velocity variation

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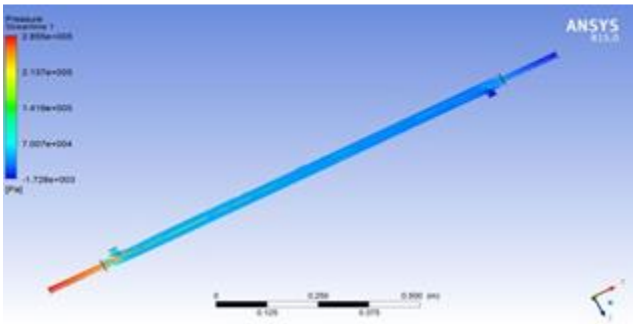
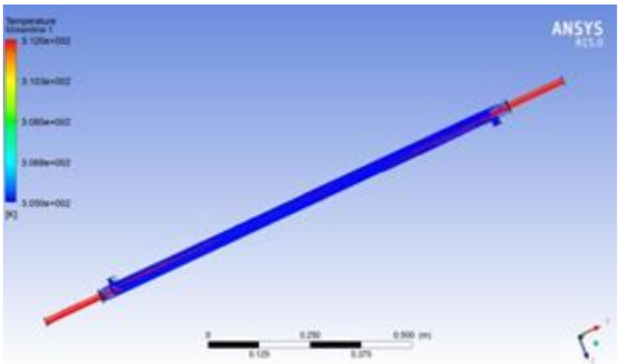
5.3 Turbulent flow in a double pipe heat exchanger for "Al" material

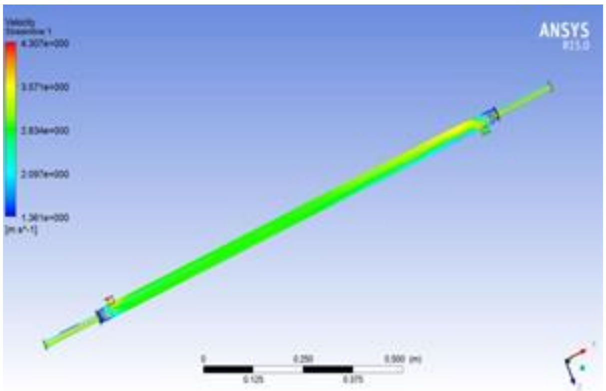
5.3.1 Temperature, pressure & Velocity Profiles for parallel flow



Temperature variation

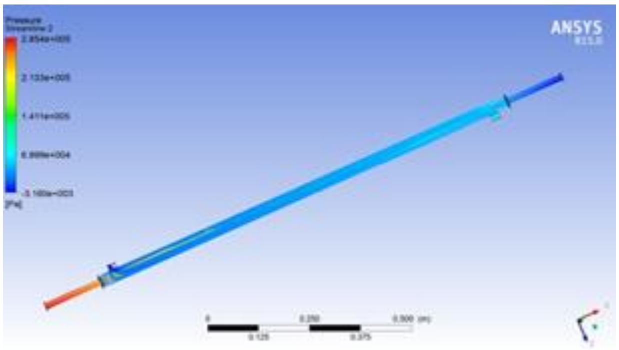


Pressure variation

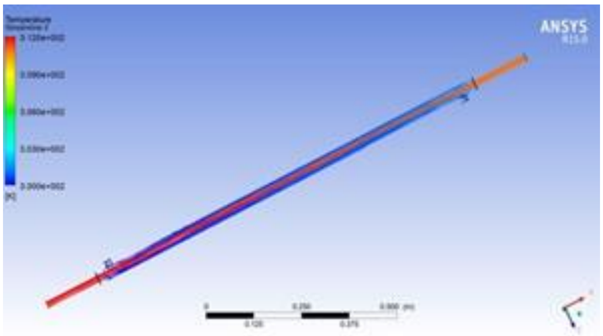


Velocity variation

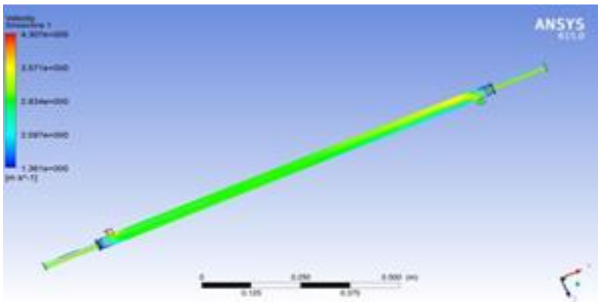
5.3.2 Temperature, pressure & Velocity Profiles for Counter flow



Pressure variation



Temperature variation



Velocity variation

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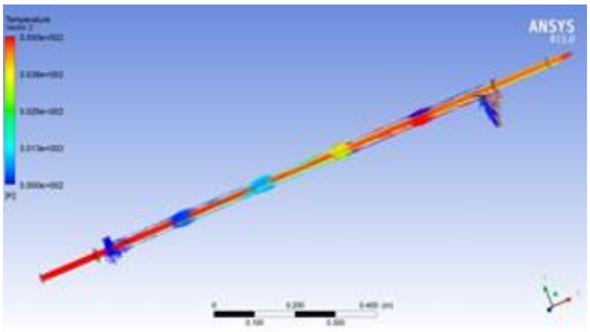
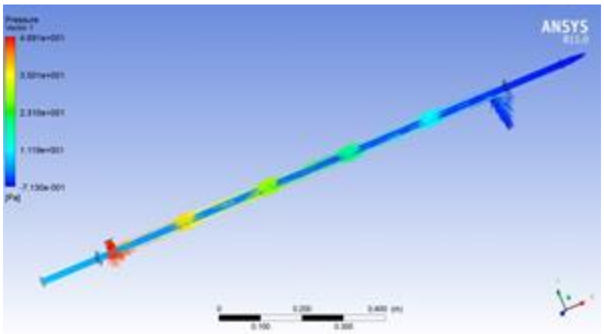
5.4 Laminar parallel flow

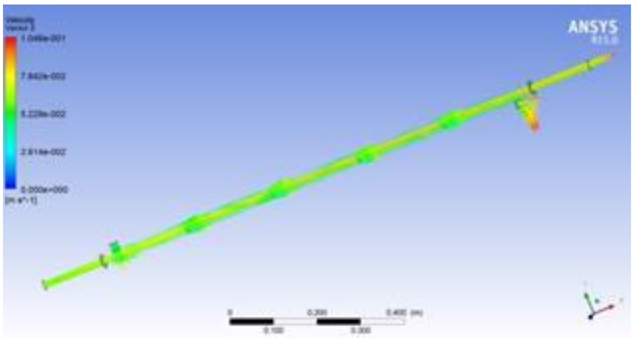
5.4.1 Temperature, pressure & Velocity Profiles



Temperature variation



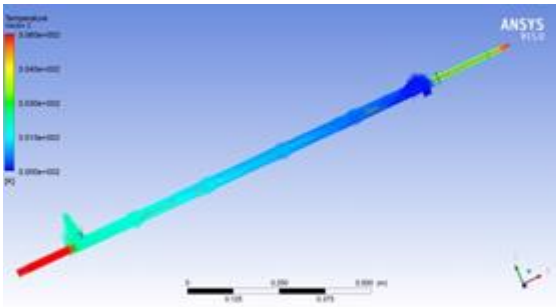
Pressure variation



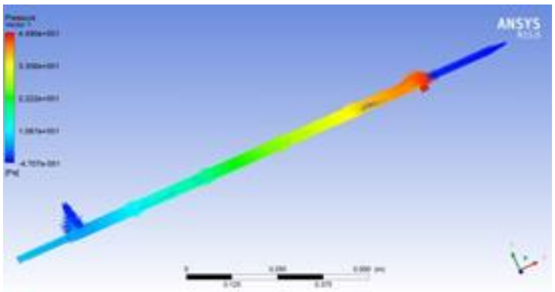
Velocity variation

5.4.2 Laminar counter flow

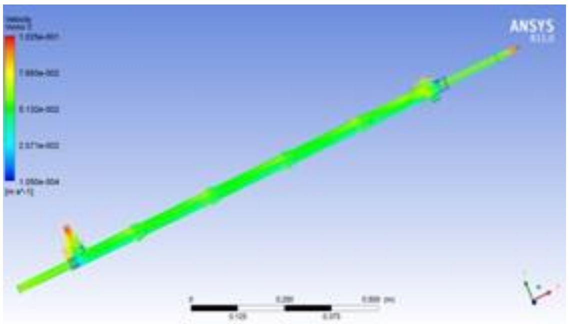
Temperature, pressure & Velocity Profiles



Temperature variation



Pressure variation



Velocity variation

6. CONCLUSIONS

In Parallel flow arrangement, considering laminar flow. At a flow rate of 0.02 m/s by using Glycerine fluid acquired better heat transfer of **275.666 watts.**

In counter flow arrangement, considering laminar flow. At a flow rate of 0.02 m/s by using Glycerine fluid acquired better heat transfer of **285.1023842 watts**. Hence, Glycerine fluid in counter flow arrangement is better effective.

Now the whole experiment is performed using **CFD** analysis in turbulent flow arrangement, which is further classified into parallel & counter flow for different fluids and materials like copper and aluminium. Aluminium exhibited better Co-efficient of heat transfer (Q_A) than that of copper, along with the fluid glycerine at different mass flow rates in both counter flow & parallel flow arrangement's, so it is concluded that Double pipe heat exchanger using Aluminium material with glycerine as fluid is more efficient compared to copper material & other fluids.

In Aluminium tube material, Parallel flow arrangement considering turbulent flow. At a flow rate of 2.4 m/s by using Glycerine fluid acquired better heat transfer of **4942.201 watts.**

In Aluminium tube material, counter flow arrangement considering turbulent flow. At a flow rate of 2.4 m/s by using Glycerine fluid acquired better heat transfer of **5693.850461watts.** Hence, Glycerine fluid in counter flow arrangement is better effective.

Further the experiment is carried out by introducing baffle segmental at different angular orientations like 0º, 45º, 90º & 135º above the surface of the inner pipe of Double pipe heat exchanger using Aluminium material. Since the Aluminium material is affirmed to be more efficient than copper. The experiment is performed using **CFD** analysis in laminar and turbulent flow arrangement, which is further classified into parallel & counter flow for Glycerine fluid.

In Aluminum tube material inserted with Baffle segmental at anangle of 45º counter flow arrangement considering laminar flow. At a flow rate of 0.02 m/s by using Glycerine fluid acquired better heat transfer of **8494.884watts.**

In Aluminium tube material inserted with Baffle segmental at an angle of 45º counter flow arrangement considering turbulent flow. At a flow rate of 2.4 m/s by using Glycerine fluid acquired better heat transfer of **11821.26542watts.** Hence, The Aluminium tube material inserted with Baffle segmental at an angle of 45º counter flow arrangement considering turbulent flow. At a flow rate of 2.4 m/s by using Glycerine fluid is better effective.

At first, the main objective of this project is to create a validation between **Experimental** &**CFD** results which was performed using different organic solutions like Glycerine, Ethylene glycol, Acetone, Benzene and Transformer oil to check the percentage error, in order to affirm the experimental setup. As the percentage of error is within 6% the experimental setup is validated.

The study results resolved that the double pipe heat exchanger with baffle segmental at 45^0 angular orientation using glycerine as working fluid give better heat transfer.

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