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CFD Analysis of Shall and Twisting Tube Heat Exchanger

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Abstract

In this research, a heat exchanger was designed and analyzed using ANSYS software. Three heat exchangers were designed:1-shall and regular tube heat exchanger ,2- shall and square cross-section twisting tube heat exchanger and 3- shall and circular cross-section twisting tube heat exchanger. The metal used in manufacturing the shall and tube is copper. It was observed that the external surface of shall is no heat take place through its. Air was used as a fluid in heat exchanger, with cold air flowing inside the tube and hot air flowing inside the shall. The counter flow inside heat exchanger. Both fluids had 1m/s velocity at the inlet suction. It was result that the temperature of the air coming out of the circular tube is colder compared to a regular tube. Additionally, in the shall and square-cross section twisting tube heat exchanger, the pressure was higher at outlet compared to regular tube.

Keywords: Shall and Twisting Tube Heat Exchanger, CFD, ANSYS Software.

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Introduction

A heat exchanger is a device that changes the temperature of fluids by flowing them across tubes surrounded by another fluid or medium. The other medium is high temperature. If we want to warm the fluid by flowing it across a tube that is surrounded by another high-temperature fluid. Conversely, if we want to cool the fluid by flowing it across a tube that is surrounded by another low-temperature fluid. The shall and tube heat exchanger is widely considered the most applied used in various manufacturing operations.

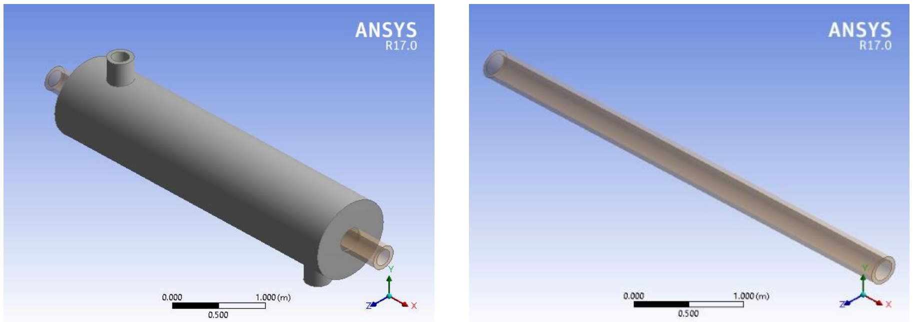
(Jahanmir & Farhadi, 2012) A comparison was carried out by using CFD simulations for a heat exchanger that had inner a circular section tube and another a heat exchanger that had inner a rectangular section tube. Result indicated that heat exchanger with a circular section tube proves an improvement 2.5% in rate heat transfer compared with heat exchanger with a rectangular section. Additionally, it was observed that the heat exchanger with a circular section practically A higher pressure drop for compared to a rectangular section. (Sathish Kumar et al., 2023) The investigation concentrated on the effect of the design of a heat exchanger with a wavy inner tube. Analysis of the data using the ANSYS software revealed that the highest heat transfer comes from a tube with 16 waves under conditions of counter flow. Also, the heat flow increases by 27% compared to a regular straight pipe. (Khaled & Mushatet, 2023) studying the effect material that a shall and tube heat exchanger was made by using three different types of metal (copper, steel 1008 and ss304). It was found that a copper heat exchanger gives best heat transfer compared to other metals used. (Mishra, 2015) An experimental study was conducted on a corrugated tube to find the effect of pressure and heat transfer. It was found that heat transfer is a rise but pressure is a decrease while using corrugated tubes. (Ghazanfari et al., 2023) To determine the thermal performance of regular and corrugated pipes, the effect of heat transfer for regular and corrugated pipes was studied. It was found that there was an improvement in heat transfer by a percentage ranging from 21.6%-60.5%. (Yang et al., 2019) Experimentally it was discussed inserting three twisted tapes into the tube. The results showed that the inclusion of twisted tapes causes a rise heat transfer through the average player. (Dabestani & Kahani, 2024) This paperwork compared experimentally between –TTT- twisted trilobed tube and –TOT- twisted oval tube by Reynolds number of 8000-21000.The results show that TTT provides better heat transfer compared with TOT, Centrifugal forces are generated due to tangential velocity and radial velocity, it is found raise temperature approach the surface wall of the tube. (Kamel et al., 2018) with turbulent flow, the study experimentally investigates the enhancement of heat using various twisted tape-includes tube configurations. Constant heat flux is used on the external surface of the tube. It is found that applied twisted tapes cause a raised thermal efficiency compared to the regular tube. The inclusion of twisted tape within the tube results in to rise the rate heat transfer and pressure drop. Because of the simple components and use of twisted tape, they have been used for the made of rotational flow in liquids over the past few decades. The size of heat exchangers can be dramatically decreased when twisted tape is applied to obtain the required heat.

Procedure of CFD Analysis

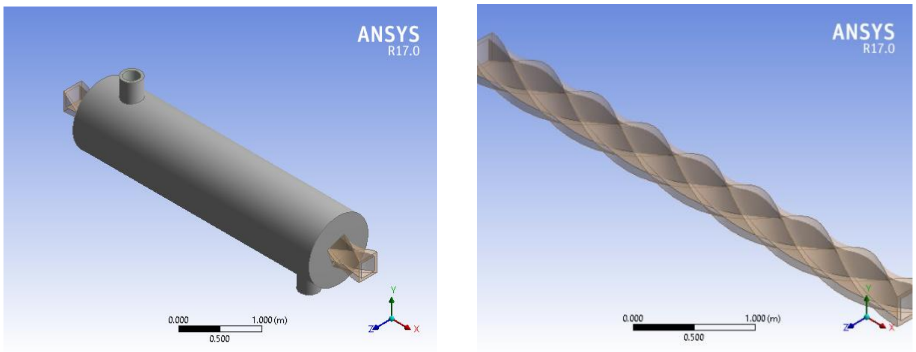
A comparison was made of three heat exchangers, shall and circular tube heat exchanger, shall and square twisting tube heat exchanger and shall and circular twisting tube heat exchanger using CFD analysis by the ANSYS software. This analysis included the following steps:

Geometry

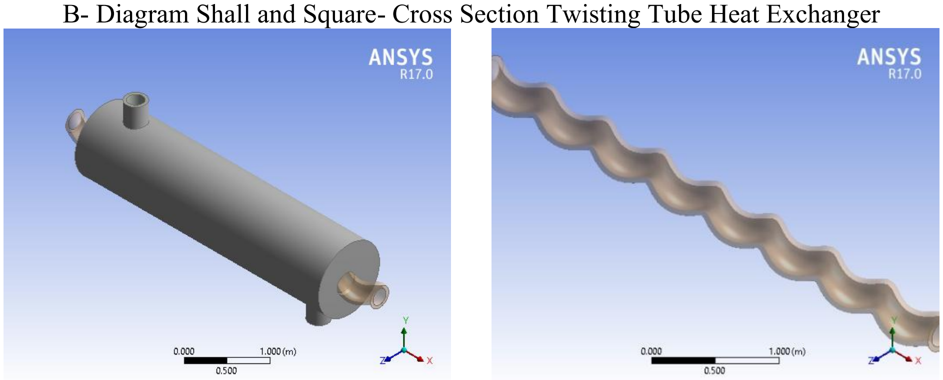
The geometry includes a set of tools, shapes and dimensions that contribute to drawing the desired shape for the heat exchanger. It is drawing a 2-D diagram and converted into a 3-D diagram by extruding with the desired length as shown in Figure 1. Table 1 includes the geometric parameters that may be required:



A- Diagram Shall and Circular Tube Heat Exchanger



B- Diagram Shall and Square- Cross Section Twisting Tube Heat Exchanger



C-Diagram Circular- Cross section Twisting Tube Heat Exchanger

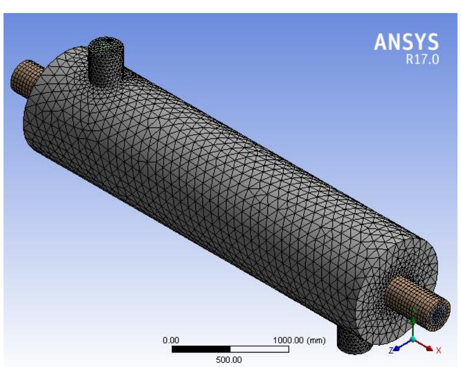
Fig. 1: Diagram Type of Heat Exchangers

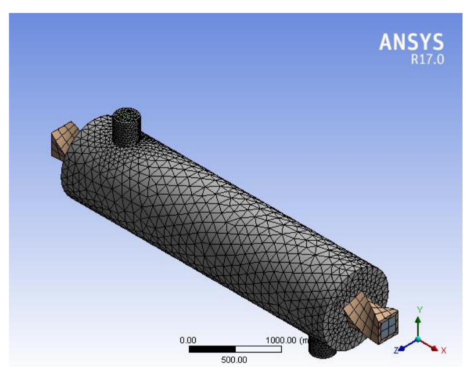
Table 1: The Geometric Parameters for Heat Exchanger

Symbol	Parameter	Value(m)
D1	Diameter of shall tube	1
D2	Hydraulic Diameter of inner tube	0.3
D3	Diameter of inlet and outlet shall	0.3
t1	Thickness of shall tube	0.4
t2	Thickness of inner tube	0.4
L	Length of shall	5
t	Turn of twisting tube	2

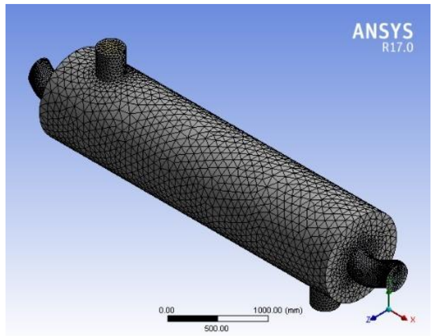
Meshing

Meshing is dividing modeling into smaller elements known as cells. It contains hexagonal and quadruple cells with triangular and quadrilateral faces. It is important to ensure that the mesh is denser towards the outer edges, taking into account the creation of boundary layers on walls. Our meshed model is shown in Figure 2.





A- Meshing Diagram Shall and Circular Tube B- Meshing Diagram Shall and Square- Cross Section



C-Meshing Diagram Shall and Circular- Cross Section Twisting Tube Heat Exchanger

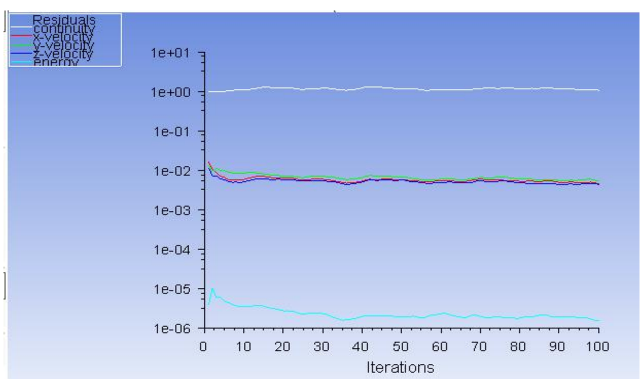
Fig. 2: Meshing Diagram of Heat Exchangers

The Setup

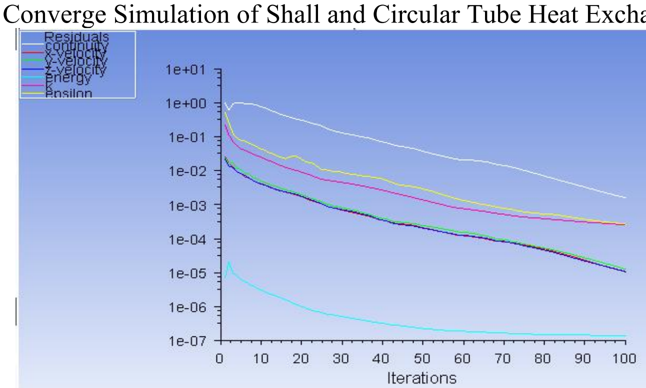
The analysis is achieved by ANSYS-FLUENT-17.in general option, solver fluent steady time was selected, solver pressure type and absolute velocity formation were selected for the analysis. In models option energy equation is On and viscous is chosen k-epsilon model, Realizable, scalable wall functions. in cell zone conditions is choose air as hot and cold fluid and copper as the material for shall and tube walls. the boundary condition at inlet hot fluid was 1 m/s velocity and 90 ºC temperature. The boundary condition at inlet cold fluid was 1 m/s velocity and 15 ºC temperature

The Solution

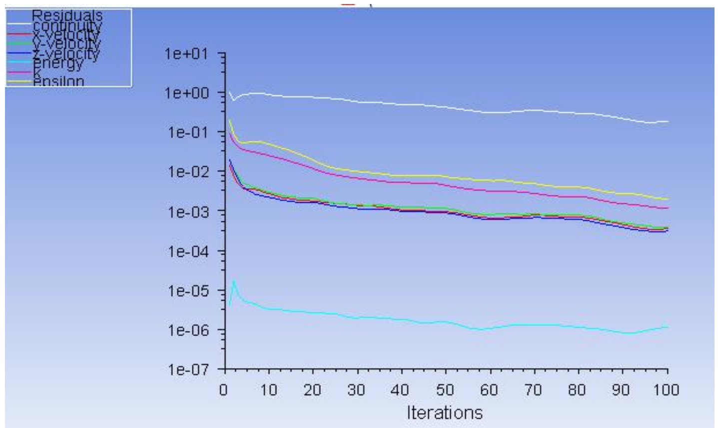
Pressure velocity coupling was selected as coupled in spatial discretization gradient selected as least squares cell based ,pressure second order, momentum second order upwind, turbulent kinetic energy, turbulent dissipation rate second order upwind ,energy second order up wind.in solution controls selected pressure 0.5,pessure 0.5,density 1, body force 1,turbulent kinetic energy 0.8,turbulent dissipation rate 0.8,turbulent viscosity 1,and energy 1.the solution initialization was set as hybrid initialization. Run calculation selected number of iterations 100. converge simulation is necessary to obtain the parameter shall and tube at out let as shown in fig.3



A- Converge Simulation of Shall and Circular Tube Heat Exchanger



B- Converge Simulation of Shall and Square- Cross Section Twisting Tube Heat Exchanger



C-Converge Simulation of Circular- Cross Section Twisting Tube Heat Exchanger

Fig. 3: Converge Simulation of Heat Exchangers

Result and Discussion

To prove the validity of the current model, the experimental results from research (Singh, & Kumar, 2014) were compared with the theoretical results using the ANSAS program. The experimental operation (Singh, & Kumar, 2014) included making a heat exchanger with counter flow condition and using the two values of volumetric flows: 2 L/m and 3 L/m for the hot and cold fluid. Table -2- shows the results of **Experimental** for (Singh, & Kumar, 2014) and **theoretical for this model**. Figure 4 shows temperature distribution through heat exchangers for a 3 L/m counter flow rate. It was found that the error rate is 1.2 % approximately

Table 2: Shows the Results of Experimental and Theoretical

Flow rate L/m	Type out fluid	Temperature Experimental(K)	Temperature Theoretical(K)
2	T_{hot} fluid out	320.1	316.19
	T_{cold} fluid out	302.5	305.16
3	T_{hot} fluid out	321.8	317.69
	T_{cold} fluid out	301.4	304.84

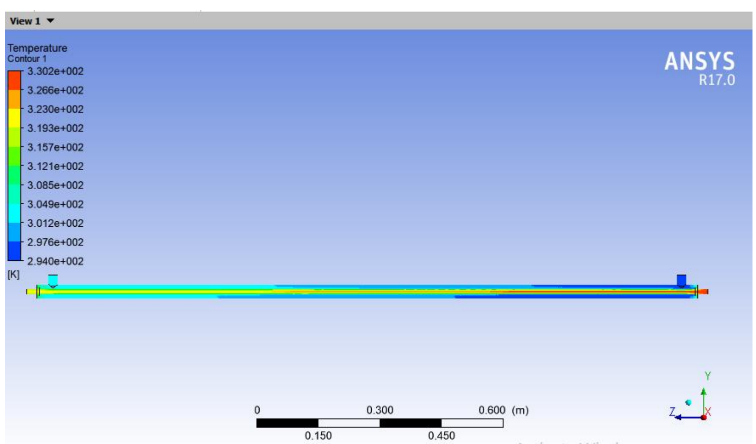
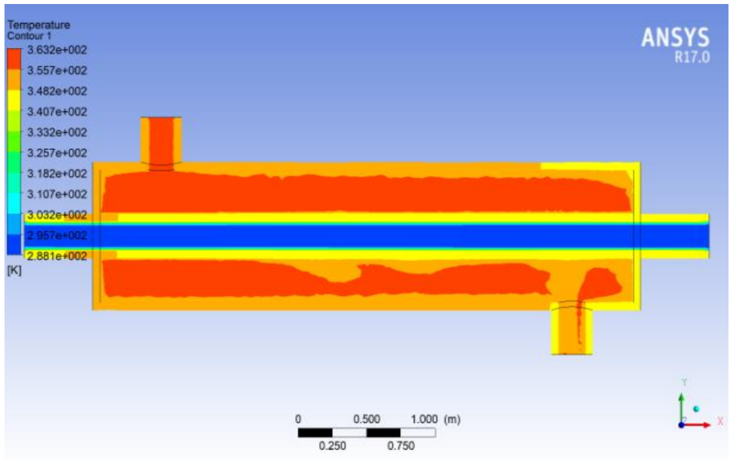


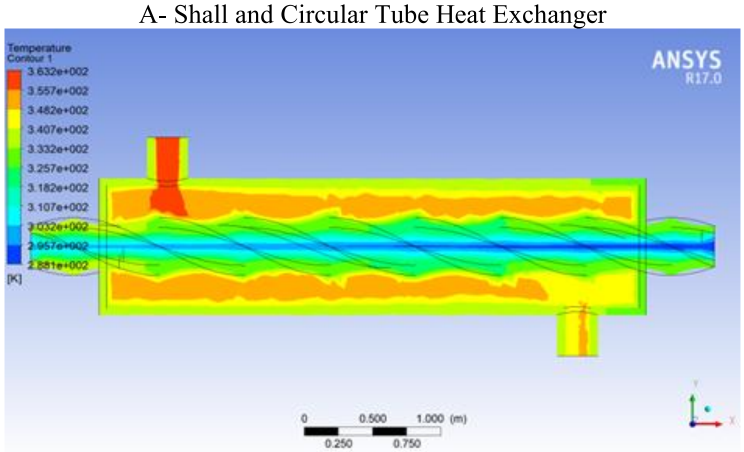
Fig. 4: Temperature Distribution for 3 L/m Counter Flow Rate

Variation of Temperature

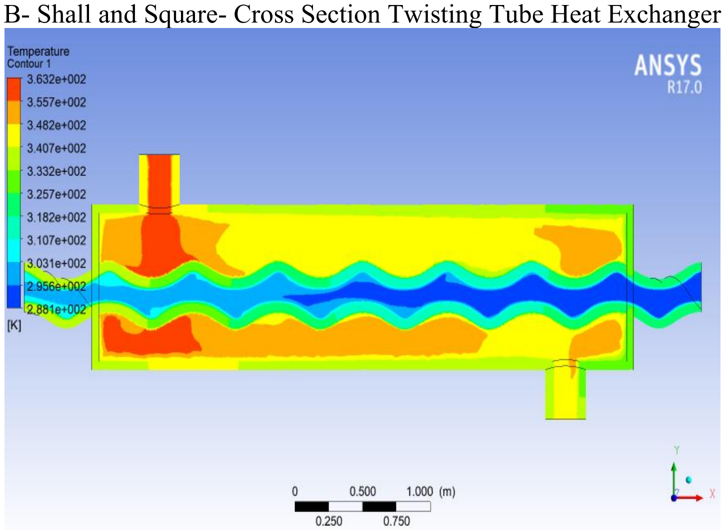
Temperature distribution across heat exchangers is given in Figure 4. Three types of heat exchanger: shall and square twisting inner tube, shall and circular twisting inner tube and shall and circular inner tube. The hot air has 363 K Temperature at the inlet and the cold air has 288 K the temperature at the inlet. Figure 5 shows the comparison between the outlet temperature for the hot fluid, showing that lowest temperature is within shall and circular- cross section twisting tube. Figure 6 shows the comparison between the outlet temperature for the cold fluid, where observed that higher temperature is within shall and circular- cross section twisting tube heat exchanger, result from figure 6, 5 the effect of surface area due to difference in the cross-section of the inner tube, these similar results were reports .



A- Shall and Circular Tube Heat Exchanger



B- Shall and Square- Cross Section Twisting Tube Heat Exchanger



C- Shall Circular- Cross Section Twisting Tube Heat Exchanger

Fig. 4: Temperature Distribution Type of Heat Exchangers

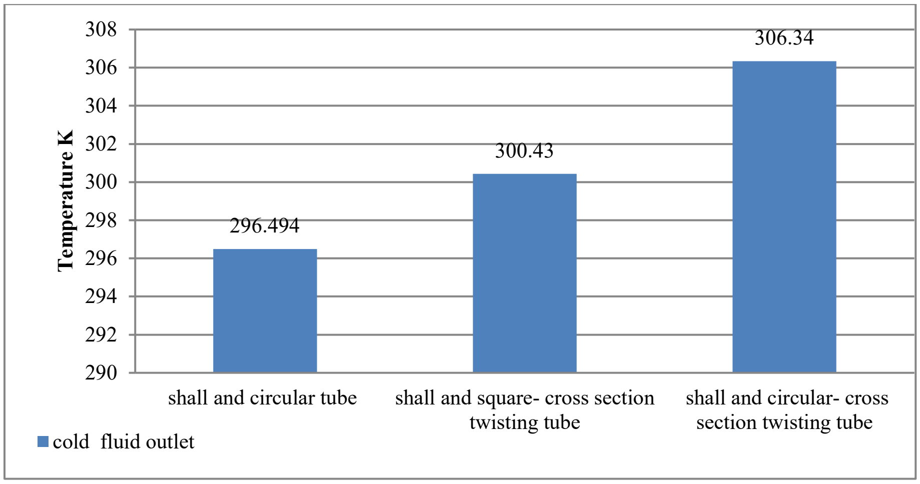


Fig. 5: Cold Outlet Temperature for Heat Exchangers

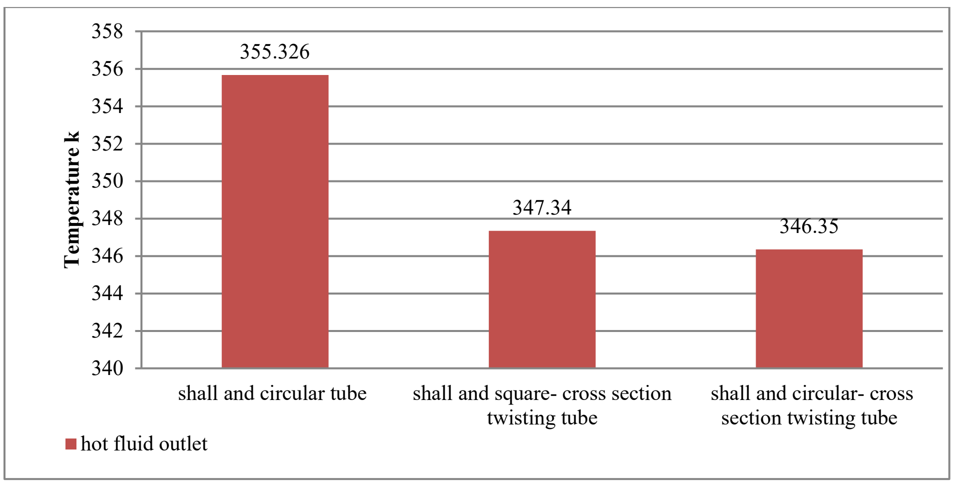
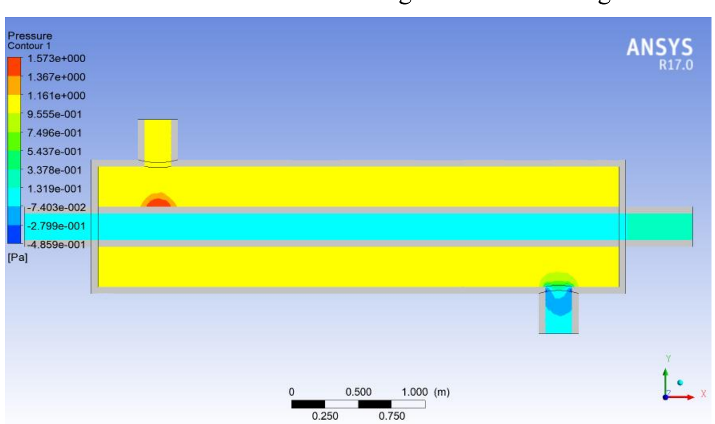


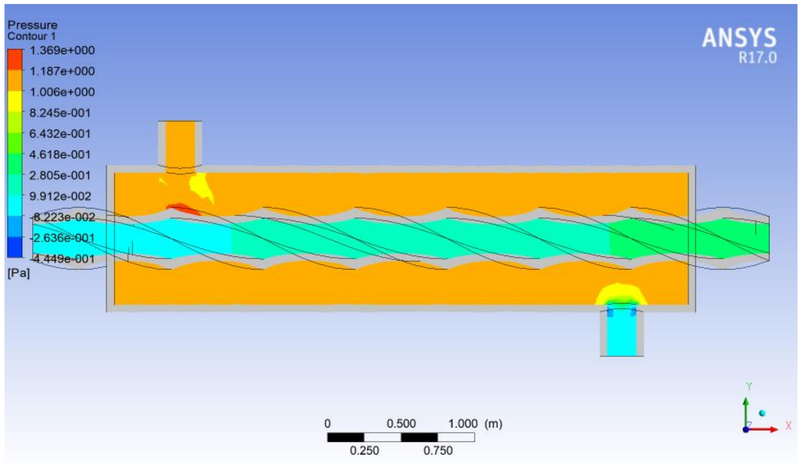
Fig. 6: Hot Outlet Temperature for Heat Exchangers

Variation of Pressure

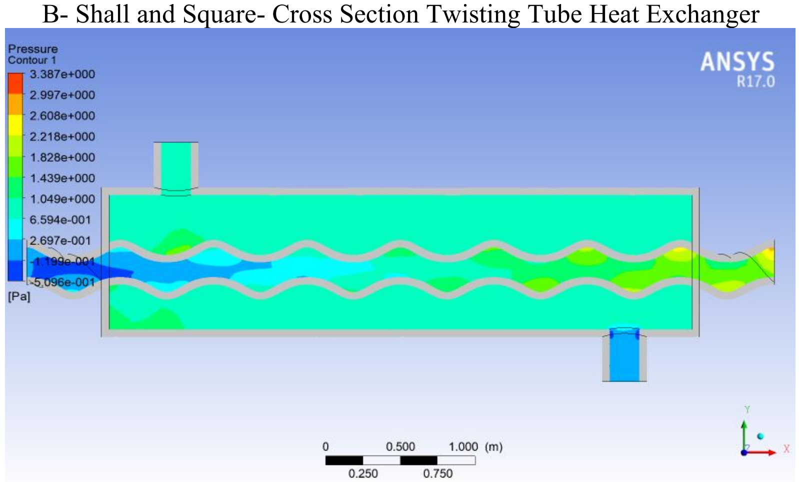
Pressure plots across the heat exchanger are shown in Fig.7. From the figure, it is observed that for the shall and square- cross section twisting tube heat exchanger, the highest pressure is at the outlet cold, and the lowest pressure is observed at outlet cold for the circular- cross section twisting tube heat exchanger as a same result .



A- Shall and Circular Tube Heat Exchanger



B- Shall and Square- Cross Section Twisting Tube Heat Exchanger

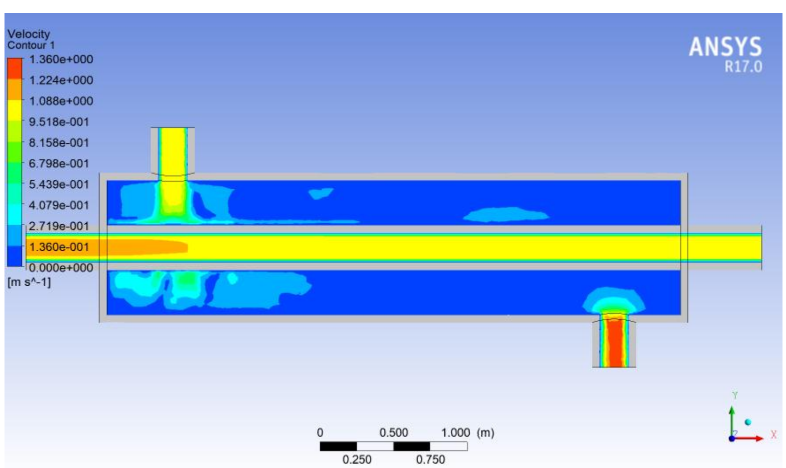


C- Shall and Circular- Cross Section Twisting Tube Heat Exchanger

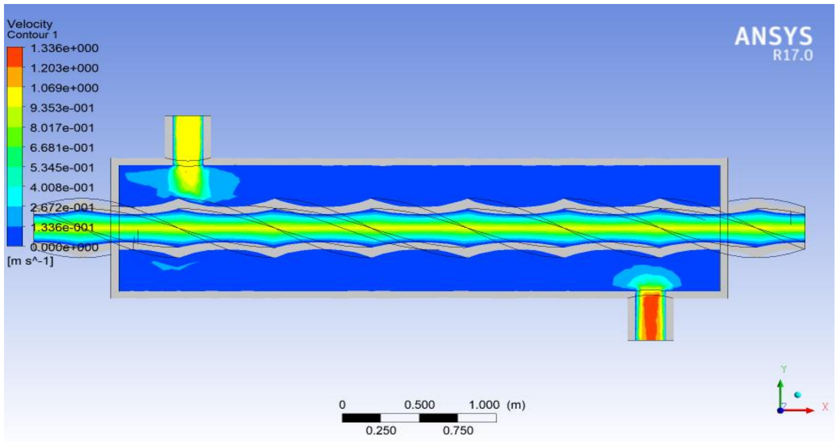
Fig. 7: Pressure Distribution Type of Heat Exchangers

Variation of Velocity

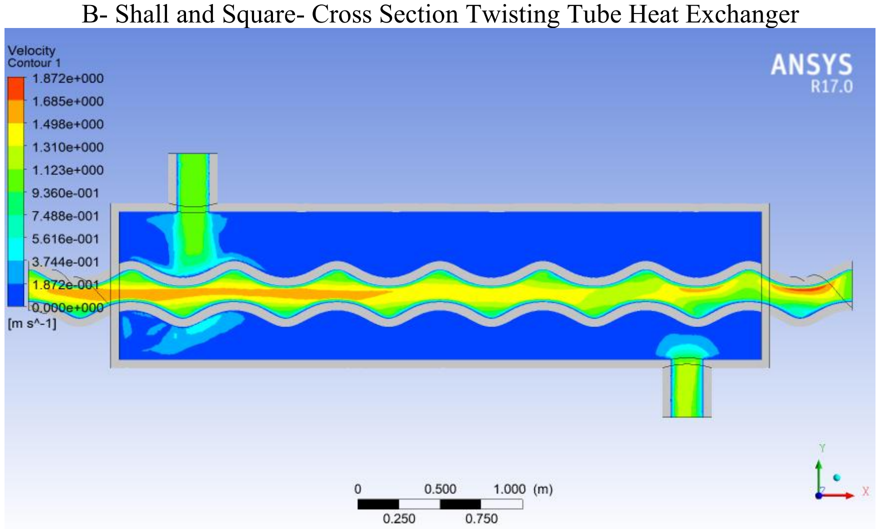
The velocity profile across the heat exchanger is given in the Figure 8. Where the velocity at the inlet is the same value for the third type of tube but at the outlet, each type of tube has a different velocity value, this same report. As shown in figure 8



A- Shall and Circular Tube Heat Exchanger



B- Shall and Square- Cross Section Twisting Tube Heat Exchanger



C-Shall and Circular- Cross Section Twisting Tube Heat Exchanger

Fig. 8: Velocity Distribution Across Type of Heat Exchangers

Conclusion

In this study, we chose copper as material for heat exchanger made then Analysis it in ANSYS software and the best possible value of temperature differences amongst the discussed materials. The following conclusion from this working:

1. Cold air flowing through counter tubes gives 296.494 K at an outlet which decreases from 288K. Hot air flowing through counter tubes gives 355.326 K at an outlet which decreases from 363 K.
2. Square cross section inner tube pattern gives 300.43 K temperature of cold air flow at an outlet and hot air flowing through circular tubes gives 347.34 K temperature at an outlet.
3. The inner tubes with circular cross section has an outlet temperature of 306.34 K for cold air flow and 346.35 K for hot air flow at outlet.

So, after comparing these results we found the maximum heat transfer occurs with a circular-cross section heat exchanger. Circular cross-section design is the optimum design for maximum heat transfer

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