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Modelling the effects of cooling moderate liquid on heat exchanger

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ABSTRACT: In present day triple tube heat exchanger is the most common type heat exchanger widely use in ventilation & air conditioning systems, oil refinery and other large chemical process, because it suits high pressure application. The process in solving simulation consists of modelling and meshing the basic geometry of triple tube heat exchanger using CFD package ANSYS 14.0. The objective of the project is design of triple tube heat exchanger and study the flow and temperature field inside the triple tube using ANSYS software tools. The heat exchanger contains 3 tubes and 500 mm length triple tube diameter 75 mm. In simulation will show how the flow pattern in the triple tube of the heat exchanger with heat transfer effects the efficiency due to the new design of the geometry of triple tube, which results in a significant increase in heat transfer coefficient per unit pressure drop in the heat exchanger spaced reduced.

KEY WORDS: heat exchanger; tube shapes; flat tube; thermal-hydraulics; CFD simulation.

I. INTRODUCTION

Heat transfer equipment is defined by the function it performs in process. The purpose of any of this equipment maximizing the heat transferred between the two liquids [1].
A simulation of any process in industry is performed by manufacturing a small prototype and subjecting the prototype to the same boundary conditions that would be performed on a real part. This process is costly and takes a long period of time due to the repetitive manufacturing process. Therefore, with the development of computer programming and today's computational fluid dynamics (CFD) numerical analysis is used instead of a prototype. CFD is a very useful process in analysing problems involving heat transfer and fluid flow and includes three phases. It is the creation of the three-dimensional geometry of a triple tube heat exchanger using computational fluid dynamics (ANSYS-FLUENT 15) [2]. Improved heat transfer has been introduced into many areas of industrial and scientific applications. This paper provides an additional review on improving heat transfer using a comparison of liquid oxygen and water coolant [3]
The technical level of the construction of the heat exchanger largely judges the effectiveness of investments and their economic return. Thus reducing costs is an important goal for both designers, but primarily for users. Optimum heat exchanger design and operation requires an understanding of the heat transfer mechanism, design and operational requirements. The traditional approach to heat exchanger design is based on an iterative process. It has gradually changing design parameters until a satisfactory solution to custom specifications is reached. However, these methods, in addition to being time-consuming, do not guarantee an optimal economic solution [4].

II. LITERATURE SURVEY

Shell and tube heat exchangers are the most common type of heat exchangers used over the world. Heat exchangers are widely used equipment in various industries such as power generation and transportation, refrigeration industry and chemical process industries because it suits high pressure application [5].
Heat exchangers are used to transfer heat between two process streams. One can realize their usage that any process which involve cooling, heating, condensation, boiling or evaporation will require a heat exchanger for these purpose [6]. Process fluids, usually are heated or cooled before the process or undergo a phase change. Different heat exchangers are named according to their application. For example, heat exchangers being used to condense are known as condensers,

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similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop [7].
A better presentation of its efficiency is done by calculating over all heat transfer coefficient. Pressure drop and area required for a certain amount of heat transfer, provides an insight about the capital cost and power requirements (Running cost) of a heat exchanger. Usually, there is lots of literature and theories to design a heat exchanger according to the requirements, where both media between which heat is exchanged are in direct contact with each other is direct contact heat exchanger, showing in figure 1.

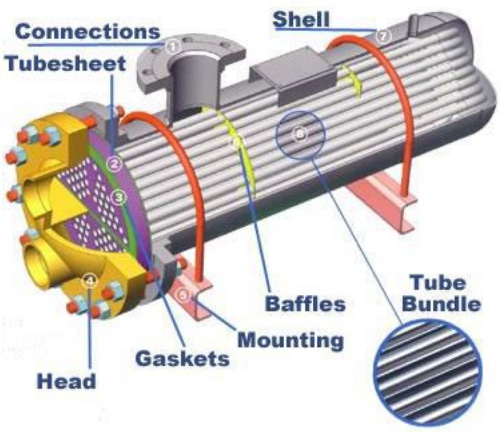

Figure1. Shell and tube heat exchangers [8]

Floating head is excellent for applications where the difference in temperature between the hot and cold fluid causes unacceptable stresses in the axial direction of the shell and tubes. The floating head can move, i.e. provides the possibility to expand in the axial direction in figure 2. They are recommended in place of fixed plate heat exchanger for high pressure and temperature operation.

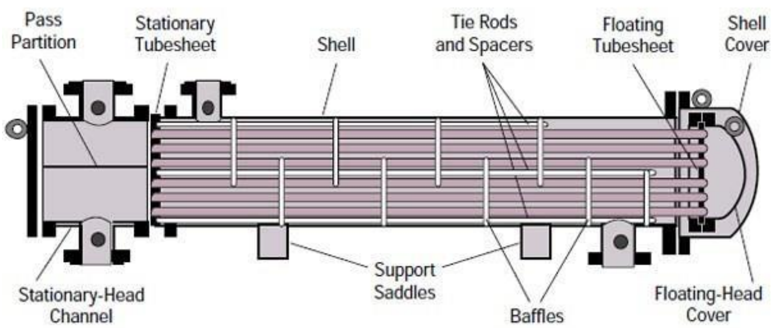

Fig 2. Floating Head Heat Exchanger [9]

The triple concentric pipes heat exchanger figure 3, is an improved version of double pipe heat exchanger. Most of the previous study on the heat exchanger is confined to two fluids and few of many possible flow arrangements; the present study involves the effect of the different liquid on heat transfer upon triple concentric pipes heat exchanger where in one cold water streams flow through the central tube and outer annular space at same mass flow rates and same inlet temperatures in co-current direction while hot water flows through inner annular space in counter-current direction.
This project proposes a basic procedure for calculating overall heat transfer coefficients and length of triple concentric pipes heat exchanger. Length of triple pipe heat exchanger is computed for a required temperature drop of hot water with available dimensions of three pipes by CFD method. Overall heat transfer coefficient and length of the equivalent triple pipe heat exchanger are compared with that of the triple pipe heat exchanger using another liquid of oxygen Liquid. The theoretical analysis shows that introducing an intermediate triple pipe to the heat exchanger reduces effective length of

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heat exchanger, which results in savings in material and space. The triple concentric pipes heat exchanger provides large heat transfer area per unit heat exchanger length and better heat transfer efficiencies compared to double pipe heat exchanger.

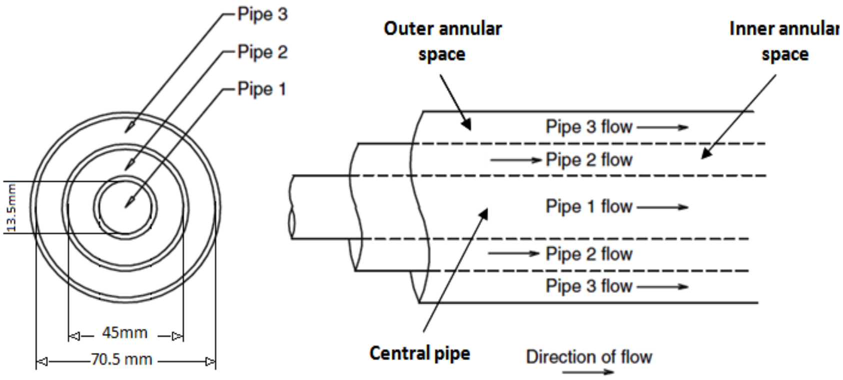

Fig 3. The triple concentric pipes heat exchanger [10]

III. SIGNIFICANCE OF THE SYSTEM

The paper mainly focuses on the process in solving simulation consists of modelling and meshing the basic geometry of triple tube heat exchanger using CFD package ANSYS 14.0. The objective of the project is design of triple tube heat exchanger and study the flow and temperature field inside the triple tube using ANSYS software tools.

IV. METHODOLOGY

A. Numerical Methodology

Triple concentric pipes heat exchanger constructed from aluminium was used to examine the effect of the liquid upon the heat transfer efficiency. A photograph and schematic triple concentric pipes heat exchanger rig are presented in Figure 4.

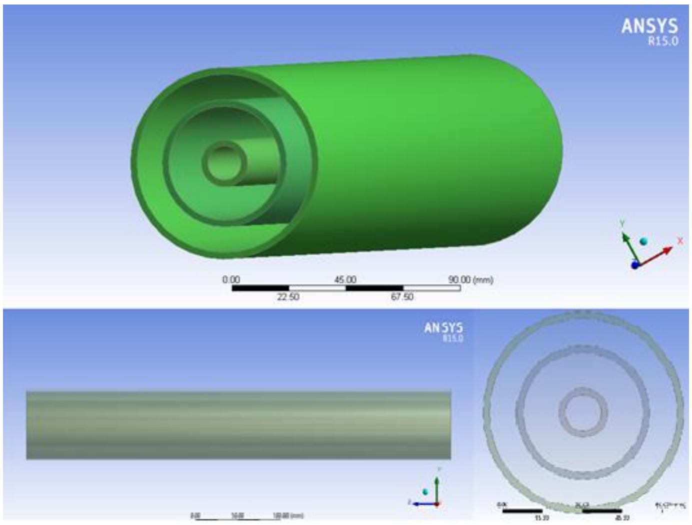

Fig 4 Schematic diagram of the triple concentric pipes heat exchanger

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- **Mesh Construction**

Figure 5. Shows two types of grid exist in CFD: structured and unstructured. The structured grids are usually created manually and consist of hexahedral elements. Unstructured grids are generated automatically and consist of a number of different element types, most of them being tetrahedrons. Each cell is used to define nodes where fluid properties are calculated. The solution is iterated at each node based on the values obtained from the neighbouring nodes. Thus, a higher number of elements results in a higher number of nodes and ultimately more calculations required, i.e. higher computation costs.

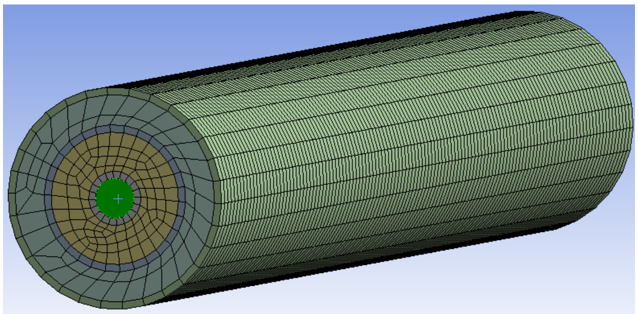

Fig 5. The triple concentric pipes heat exchanger mesh distribution

B. Test boundary conditions

The simulation was run to define the heat transfer limits and minimum efficiency could be reached regarding with the length of the triple pipe heat exchanger using the same conditions of all case to compare between tow liquids as water and oxygen represent a high percentage of the heat transfer level. The boundary conditions are specified in tables 1, 2 and 3.

Table 1. Inlet boundary conditions case 1

Inlet boundary	**Area m2**	**Mass flow rate kg/s**	**Temperature K**
Inner pipe inlet	1.9303e-3	0.001	283
Intermediate pipe inlet	1.3149e-3	0.0007	343
Outer pipe inet	1.4241e-4	0.000014	291

Table 2. Inlet boundary conditions case 2

Inlet boundary	**Area m2**	**Mass flow rate kg/s**	**Temperature K**
Inner pipe inlet	1.9303e-3	0.002	283
Intermediate pipe inlet	1.3149e-3	0.0014	343
Outer pipe inet	1.4241e-4	0.000028	291

Table 3. Inlet boundary conditions case 3

Inlet boundary	**Area m2**	**Mass flow rate kg/s**	**Temperature K**
Inner pipe inlet	1.9303e-3	0.004	283
Intermediate pipe inlet	1.3149e-3	0.0028	343
Outer pipe inet	1.4241e-4	0.000056	291

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V. EXPERIMENTAL RESULTS

A. Figure 6. Appeared the increasing of the temperature in inner pipe from 283K up to 304K while the decreasing of the temperature of the Intermediate pipe from 343 K up to 307 K, in outer pipe the temperature increasing from 291K up to 316 K ..

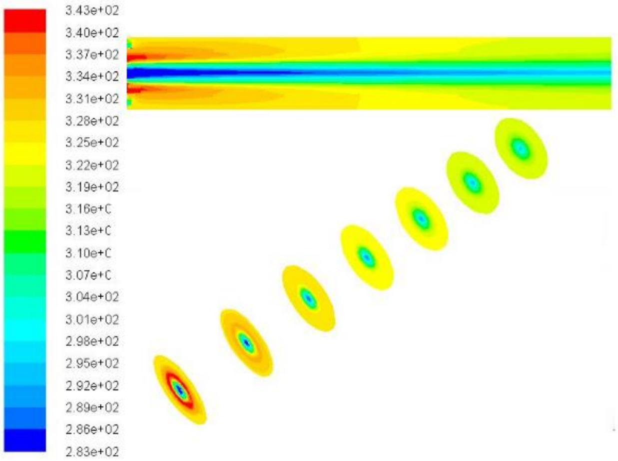

Fig 6. Temperature distributions contours using water liquid case1

B. Figure 7 case 1. Shown the contours of the temperature using oxygen liquid at the centre of the exchanger pipe which appeared the increasing of the temperature in inner pipe from 283K up to 298K while the decreasing of the temperature of the Intermediate pipe from 343 K up to 328 K in outer pipe the temperature increasing from 291K up to 325K .

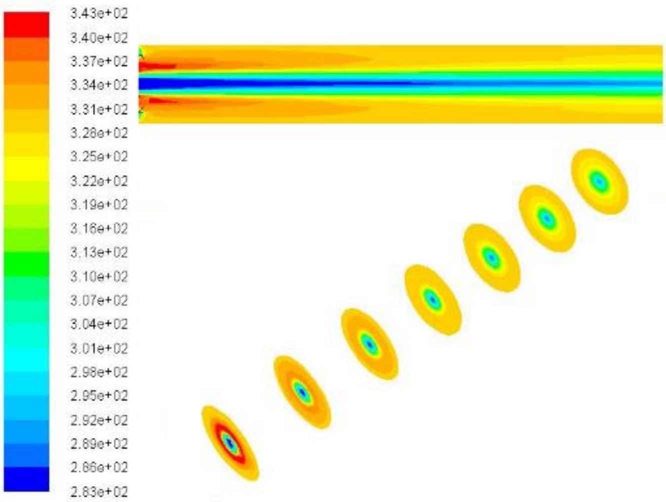

Fig 7. Temperature distributions contours using water oxygen liquid case 1

C. Figure 8 case1. Observed in the Intermediate pipe that the oxygen liquid absorption less temperature compared with that using water liquid, for ample the temperature of the oxygen reduced from 331 K up to 318K that is mean 13 K

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dropping temperature. Furthermore the temperature of water liquid reduced long the pipe from 325 K up to 316 K which observed less temperature reduced than Oxygen about 9 K .

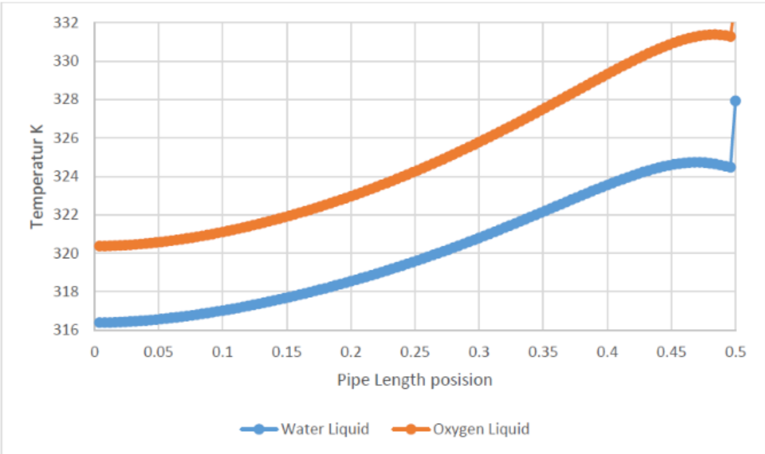

Fig 8. Comparison of heat transfer intermediate pipe between water vs oxygen case 1

D. Figure 9 case 1. Observed in the central pipe that the water liquid absorption more temperature compared with that using oxygen liquid, for example the temperature of the water increasing from 283 K up to 293 K which it gained about 10 K, while the oxygen liquid case the temperature increased from 283 K up to 289 K, which gained 6 K .

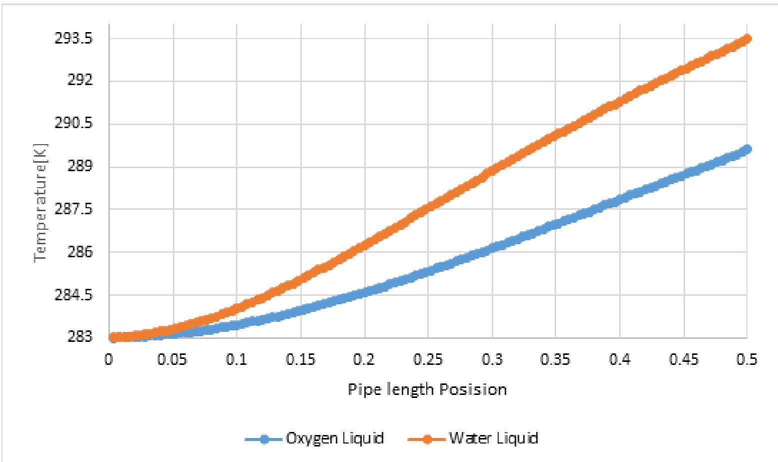

Figure 9. Comparison of heat transfer central pipe between water vs oxygen case1

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E. Figure 10. The contours of the temperature using water liquid at the centre of the exchanger pipe which appeared the increasing of the temperature in inner pipe from 283K up to 319 K while the decreasing of the temperature of the Intermediate pipe from 343 K up to 323 K, in outer pipe the temperature increasing from 291K up to 316K.

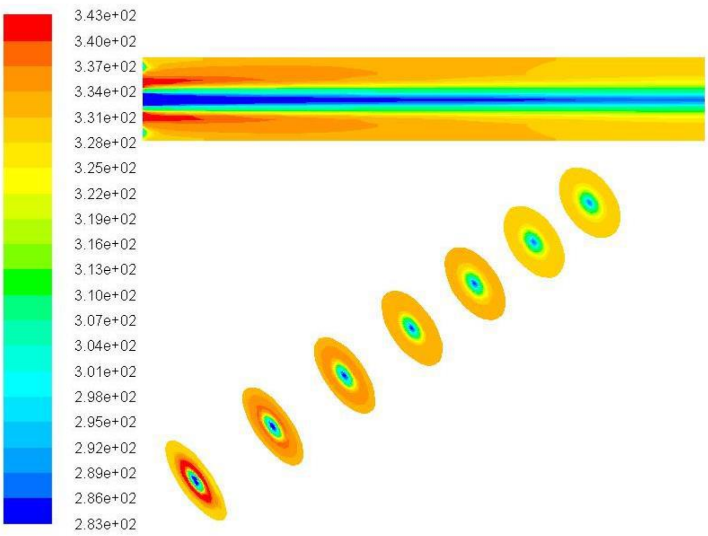

Fig 10. Temperature distributions contours using water liquid case ***2***

F. Figure 11. The contours of the temperature using oxygen liquid at the centre of the exchanger pipe which appeared the increasing of the temperature in inner pipe from 283K up to 313K while the decreasing of the temperature of the Intermediate pipe from 343 K up to 331 K, in outer pipe the temperature increasing from 291K up to 325K

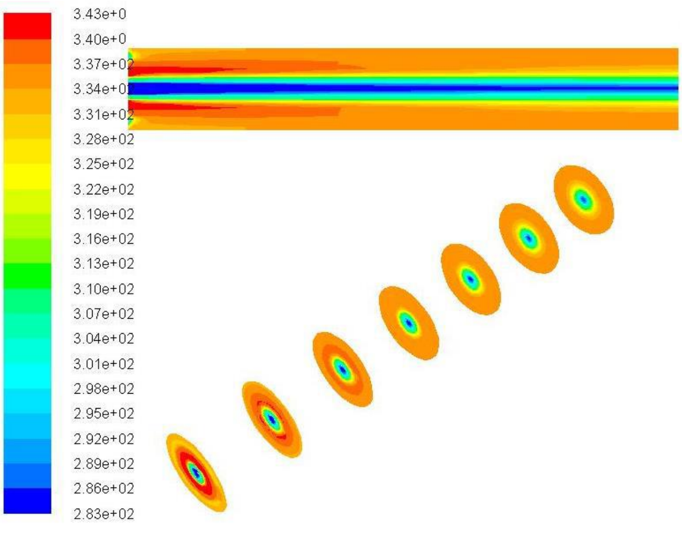

Fig 11. Temperature distributions contours using water oxygen liquid case 2

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G. Figure 12 case 2. Observed in the central pipe that the water liquid absorption more temperature compared with that using oxygen liquid, for example the temperature of the water increasing from 283 K up to 293 K which it gained about 10 K, while the oxygen liquid case the temperature increased from 283 K up to 289 K which gained about the 6 K.

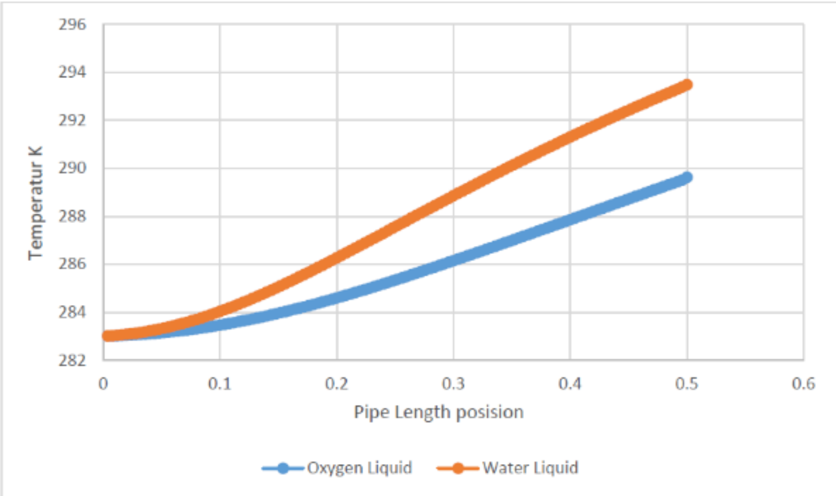

Fig 12. Comparison of heat transfer central pipe between water vs oxygen case 2

H. Figure 13 case 3. Observed in the central pipe that the water liquid absorption more temperature compared with that using oxygen liquid, for example the temperature of the water increasing from 283 K up to 288 K which it gained about 5 K, while the oxygen liquid case the temperature increased from 283 K up to 285 K which gained about the 2 K

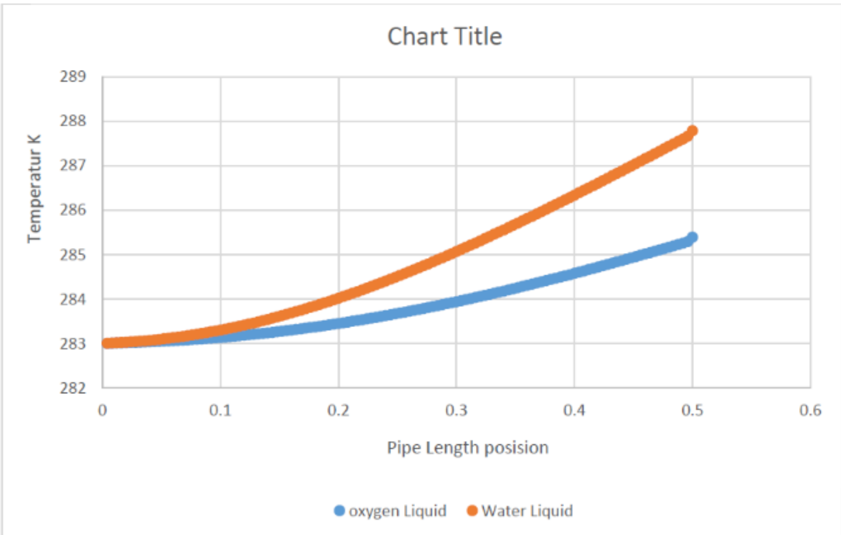

Fig 13. Comparison of heat transfer central pipe between water vs oxygen case 3

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I. Figure 14 case 2. Observed in the Intermediate pipe that the oxygen liquid absorption less temperature compared with that using water liquid, for example the temperature of the oxygen reduced from 331 K up to 318K that is mean 13 K dropping temperature.

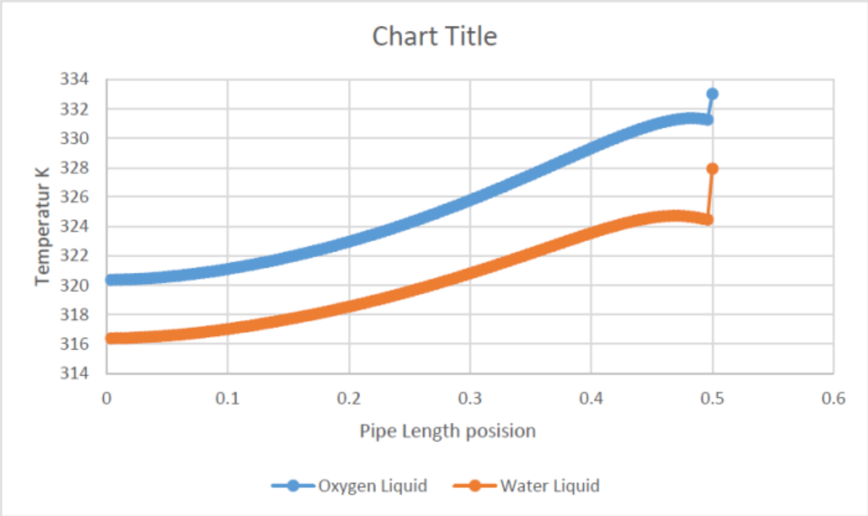

Fig 14. Comparison of heat transfer intermediate pipe between water vs oxygen case 2

J. Figure 15 case 3. Observed in the Intermediate pipe that the oxygen liquid absorption less temperature compared with that using water liquid, for example the temperature of the oxygen reduced from 334 K up to 337K that is mean 3 K dropping temperature. Furthermore, the temperature of water liquid reduced long the pipe from 336 K up to 329 K which observed less temperature reduced than Oxygen about 7 K. Despite the inlet temperature was applied on the ANSYS same but the oxygen could absorption less temperature than water liquid.

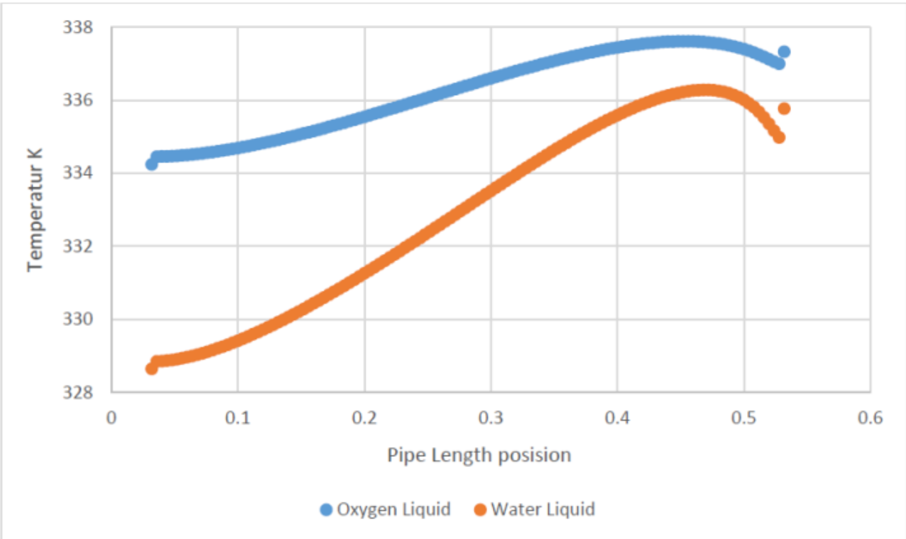

Fig 15. Comparison of heat transfer intermediate pipe between water vs oxygen case 3

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VI. CONCLUSION

The overall heat transfer coefficients and length of triple concentric pipe heat exchanger were found out using input parameters i.e. geometrical characteristics of three pipes, mass flow rates and thermos physical properties of two fluids. The length of triple pipe heat exchanger was computed for 343K temperature drop of hot water, the length of triple concentric pipe heat exchanger was found to be 0.5 m.

There are two overall heat transfer coefficients in triple pipe heat exchanger: one based on outside area of central pipe and second based on inside area of intermediate pipe.

The flow regimes in triple pipe heat exchanger were observed to be: transition in the central pipe and inner annular space and laminar in outer annular space.

REFERENCES

[1] J. Johnson and A. Shani, "CFD Analysis of Double Pipe Heat Exchanger," vol. 4, no. 5, pp. 1283–1286, 2015.
[2] K. Ravikumar, C. N. Raju, and M. Saheb, "CFD Analysis of a Cross-flow Heat Exchanger with Different fin thickness," vol. 13, no. 2, pp. 345–362, 2017.
[3] Z. K. Kadhim, M. S. Kassim, and A. Y. A. Hassan, "CFD study for cross flow heat exchanger with integral finned tube," Int. J. Sci. Res. Publ., vol. 6, no. 6, p. 668, 2016, [Online]. Available: www.ijsrp.org.
[4] J. Mičieta, V. Jiří, J. Jandačka, and R. Lenhard, "Optimization principle of operating parameters of heat exchanger by using CFD simulation," EPJ Web Conf., vol. 114, pp. 1–7, 2016, doi: 10.1051/epjconf/201611402074.
[5] D. R. Srikanth, "Heat Transfer AP Government GATE Online Classes," vol. 8, 2020.
[6] S. M. W. James R. Couper, W. Roy Penney, James R. Fair, Ed., Chemical Process Equipment, Second edi. 2005.
[7] Heat Exchangers Fundamentals." https://ez-pdh.com/quiz-help-fundamentals-heat-exchangers/.
[8] M. V. M. K.Sriharsha, V.R.Mamilla, "Strength Analysis of Tube to Tube Sheet Joint in Shell and Tube Heat Exchanger," Int. J. Sci. Eng. Technol. Res., vol. 1, no. October 2012, pp. 43–50, 2012.
[9] Floating head exchanger," 2019, [Online]. Available: https://www.enggcyclopedia.com/2019/05/shell-tube-heat-exchanger-types/.
[10] Sizing of triple concentric pipe heat exchanger," 2014, [Online]. Available: https://www.semanticscholar.org/paper/Sizing-of-triple-concentric-pipe-heat-exchanger-Ghiwala-Matawla/ec1dc61d13408cc893b8ac638dd0310063f1641f.