DESIGN AND PERFORMANCE ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER BY VARYING THE FLUID MEDIUM USING CFD

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***Abstract:** In thermal systems, heat exchangers are used to control the operating temperature of the working fluids. Shell and tube style heat exchangers are the most common kind of heat exchangers used in industries. In this work, shell and tube heat exchanger performance analysis is performed using CFD tools under industry-collected boundary conditions. Instead, the cooling liquid ammonia is replaced by Al_2O_3 and evaluated accordingly to increase the performance of the system. Instead the heat exchanger of the shell and tube is replaced by the heat exchanger of the u tube and analysed under the same boundary conditions. Then, the results are compared and the application of Al2O3 was found to have a better thermal efficiency.*

Keywords – Heat exchangers – CFD analysis – Optimization of output – Nano fluids.

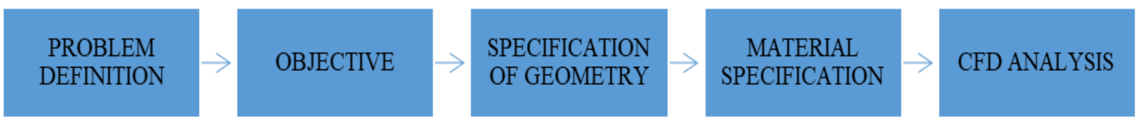
I. INTRODUCTION

In various thermal and thermal related industries, heat exchangers are commonly used to maintain a desired temperature within the device. The flow of heat occurs in many ways, one of which is convection, also known as convective heat transfer. This method of heat transfer is commonly utilized in all heat exchanger forms. Given this simple construction and less maintenance, shell and tube style heat exchangers are commonly used by different types of heat exchangers. This type of heat exchanger operates under modes of parallel and counter flow.

A shell and tube heat exchanger is taken in this project for the purpose of research. The heat exchanger model is performed using solid works software and the same package will be used for future CFD research, as this program will combine the process between modeling and simulation. The simulation data would be obtained from a nearer diary plant, as they use heat exchangers to hold the temperature within their device. The current system will first be subjected to CFD review, and the findings will then be recorded. Instead, the working fluid is switched from ammonia to titanium oxide while attempting to improve the transfer of heat from gas to liquid. This then tabulates the CFD tests and compares them accordingly.

II. METHODOLOGY

Methodology is the basic prerequisite of a project, since it establishes the correct requirements for beginning and completing the research to be completed. Proper process preparation and implementation decides the project will be successfully completed. The project's approach is as shown.



III. PROBLEM DEFINITION

Heat exchangers are commonly used heat transfer devices and are primarily used in food industries for food preservation and also for maintaining constant temperature at different points of the liquid movement. The following is the schematic of the heat transfer network of a typical food processing field.

In the diagram below, reservoir water enters the heat exchanger shell and tube as cold water. Meanwhile a compressor draws the ammonia from the accumulator and passes it under high pressure through the pipes. Since the ammonia gets pressurised, it attains some thermal heat and passes through the pipes and reaches the shell and tube heat exchanger.

Here, the cold water combines with the hot fluid and heat transfer occurs as a result. As a result, the water heats up and is sent through pipes into the reservoir. The water gets its job done over here and there during the trip. At the other side, the cooled ammonia is condensed and stored in the condenser tank, here the ammonia is in liquid state and pumped into the accumulator unit again, where it is ready to be compressed by the compressor again, and this process continues.

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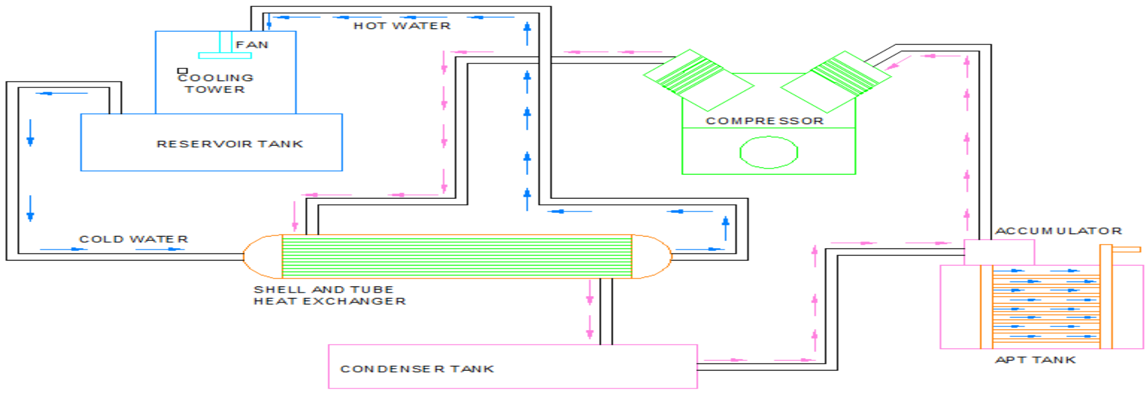

Figure 1 Thermal system of the industry

IV. OBJECTIVE

The objective of improving the condensation rate and improving the amount of liquid ammonia collected in the tank was taken on the basis of the above mentioned question. It was also noted that the application of suitable fluids would boost the rate of heat transfer resulting in increased device performance. With this approach, the aim of this project work was to optimize the heat transfer of the shell and tube heat exchanger, by varying the coolant fluid and also by varying the exchanger geometry. In this work, CFD is used to determine the heat transfer rate as well as the temperature difference between the shell and tubes and the fluid inlet and outlet conditions respectively.

V. GEOMETRY SPECIFICATION

SHELL DETAILS
Outer diameter = 142mm
Inner diameter = 136mm
Length of the HE = 1500mm
No. of baffles = 5
Distance between baffles = 300mm
Baffle opening = 25% (except first and last)

TUBE DETAILS
Outer diameter = 23mm
Inner diameter = 20mm
Length = 1200mm
No. of tubes = 9

MATERIALS DETAILS
Shell = Stainless Steel
Tubes = Copper
Baffles = Copper

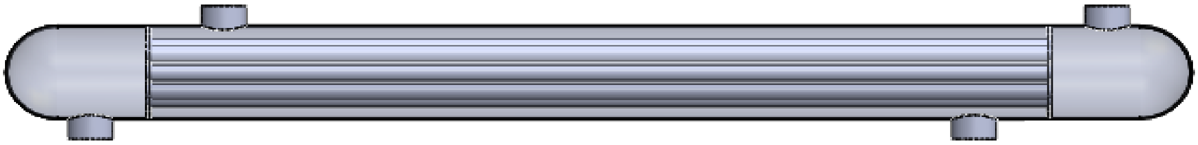

Figure 2 Shell and Tube type Heat Exchanger _ existing type

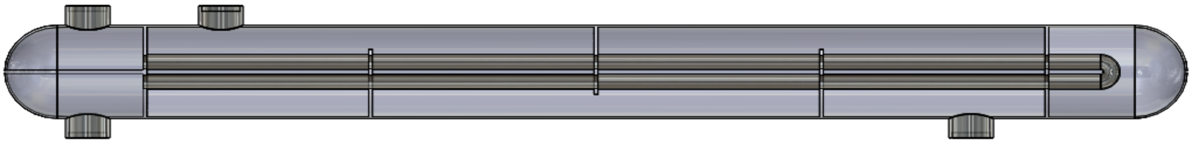

Figure 3 U-Tube type Heat Exchanger _ proposed type

VI. MATERIAL SPECIFICATION

Table 1 Material properties of NH_4 _ existing fluid

Boiling Point	-28°F
Weight per gallon of liquid at -28°F	5.69 pounds
Weight per gallon of liquid at 60°F	5.15 pounds
Specific gravity of the liquid (water=1)	0.619
Specific gravity of the gas (air=1)	0.588
Flammable limits in air	16-25%
Ignition temperature	1204°F
Vapor pressure at 0°F	16 psi
Vapor pressure at 68°F	110 psi
Vapor pressure at 100°F	198 psi
One cubic foot of liquid at 60°F expands to	850 cubic foot of gas

Table 2 Material properties of AL_2O_3 _ proposed fluid

Property	**Minimum Value (S.I.)**	**Maximum Value (S.I.)**	**Units (S.I.)**
Atomic Volume (average)	0.005	0.0058	m^3/kmol
Density	3	3.98	Mg/m^3
Energy Content	150	200	MJ/kg
Bulk Modulus	137	324	GPa
Compressive Strength	690	5500	MPa
Ductility	0.00018	0.0018	
Elastic Limit	69	665	MPa
Endurance Limit	59	488	MPa
Fracture Toughness	3.3	5	$MPa.m^{1/2}$
Hardness	5500	22050	MPa
Loss Coefficient	1E-005	0.0002	
Modulus of Rupture	152	800	MPa
Poisson's Ratio	0.21	0.33	
Shear Modulus	88	165	GPa
Tensile Strength	69	665	MPa
Young's Modulus	215	413	GPa
Glass Temperature			K
Latent Heat of Fusion	620	1360	kJ/kg
Maximum Service Temperature	1350	2114	K
Melting Point	2277	2369	K
Minimum Service Temperature	0	0	K
Specific Heat	451	955	J/kg.K
Thermal Conductivity	12	38.5	W/m.K
Thermal Expansion	4.5	10.9	10^{-6}/K

VII. CFD Analysis

The CFD analysis was conducted under the following 3 steps.

- Pre-processing
- Solution
- Post-processing

At the pre-processing stage, the model importation and cleaning, meshing, boundary conditions and assignment of material properties are all completed. Configuration for the solver and output configurations and tests are carried out at the solution level. The extraction of results from the saved database is done in post-processing in the form of contour plots and tabulated values, and this post-processing will be clarified in the next chapter.

Following are the pre-processing data used in this work.

- Inlet mass flow = 0.222 Kg/sec (Hot and Cold)
- Inlet Hot fluid temperature = 55^{o}C
- Inlet Cold fluid temperature = 25^{o} C
- Outlet conditions = Environmental temperatures and pressure (Hot and Cold)

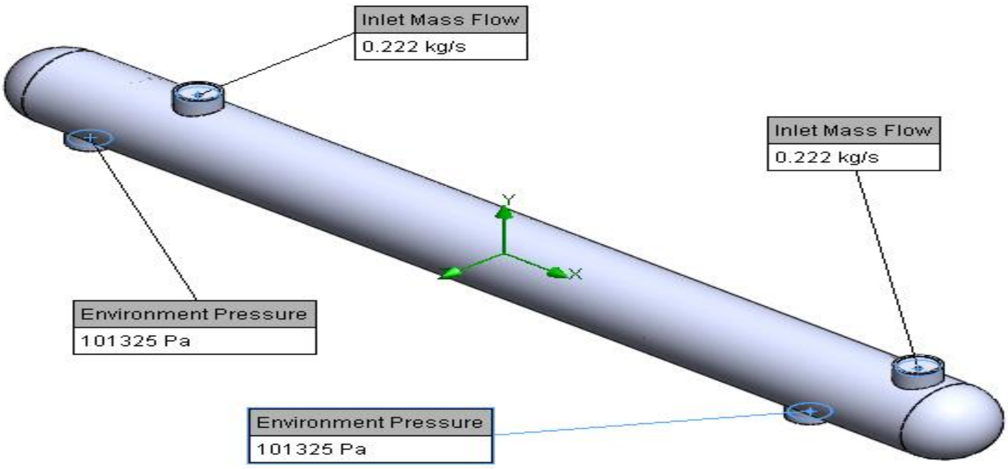

Figure 4 Boundary Conditions of the Heat exchanger used for CFD analysis

VIII. RESULTS AND DISCUSSIONS

The following are the outputs of the solved problem. This is termed as the post-processing in the CAE analysis. Here the outputs are displayed as coloured contours and graphs and tabulated readings.

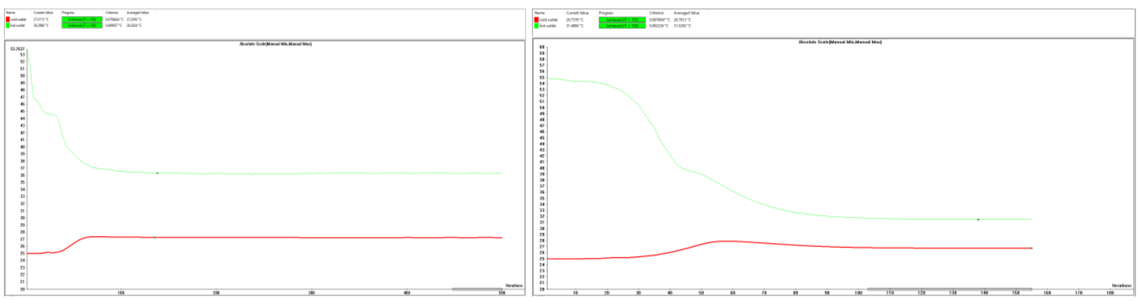

Figure 5 Convergence plot for Straight tubeHeat exchanger _ existing and proposed fluid conditions

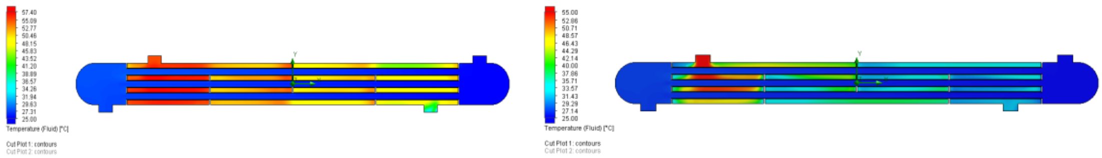

Figure 6 Temperature plot on tubes for Straight tubeHeat exchanger _ existing and proposed fluid conditions

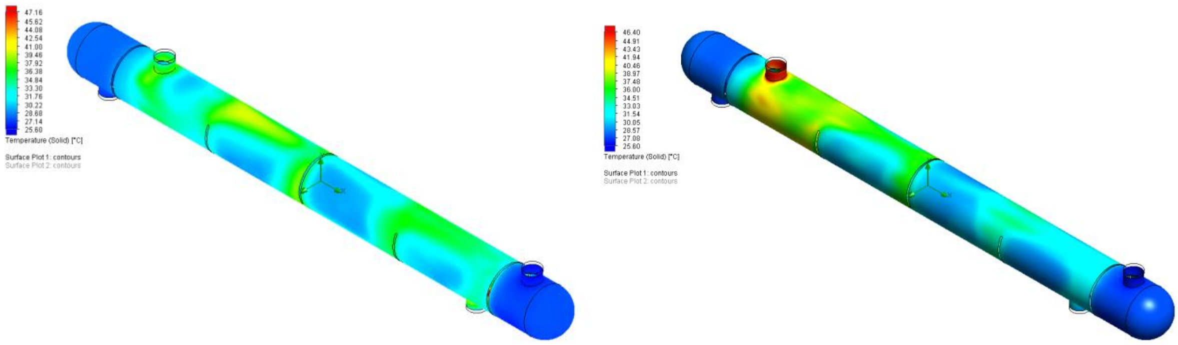

Figure 7 Surface temperature of shell for Straight tubeHeat exchanger _ existing and proposed fluid conditions

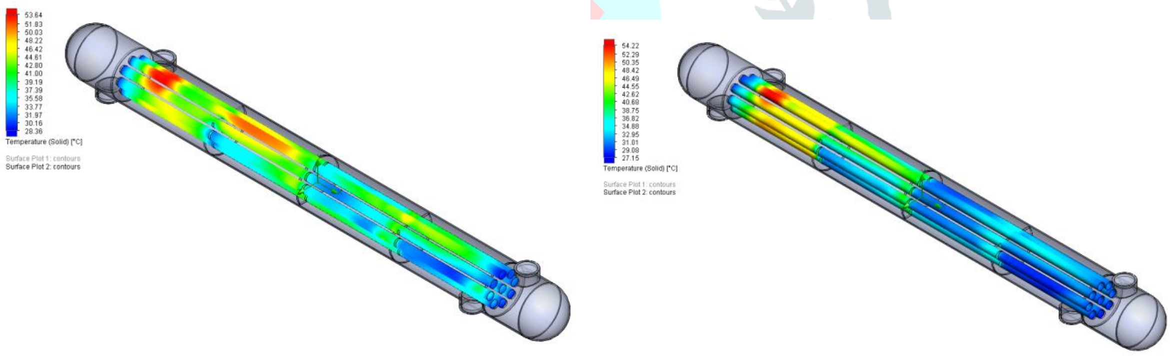

Figure 8 Surface temperature of tubesfor Straight tubeHeat exchanger _ existing and proposed fluid conditions

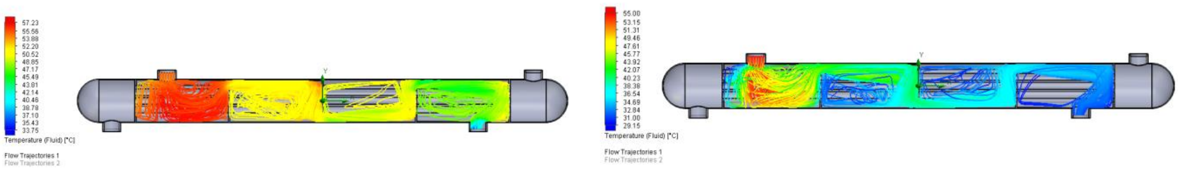

Figure 9 Fluid flow inside shellfor Straight tubeHeat exchanger _ existing and proposed fluid conditions

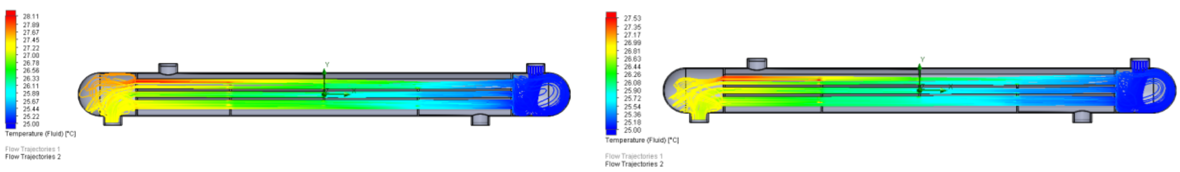

Figure 10 Fluid flow inside tubesfor Straight tubeHeat exchanger _ existing and proposed fluid conditions

Table 3 Temperature resultsfor Straight tube Heat exchanger _ existing and fluid conditions

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
NH_4 Outlet Temperature	[°C]	27.21715296	27.22949719	27.21715296	27.24292072
H_2O Outlet Temperature	[°C]	36.28875563	36.28236837	36.25782921	36.32027699

Table 4 Temperature resultsfor Straight tube Heat exchanger _ proposed fluid conditions

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
Al_2O_3 Outlet Temperature	[°C]	26.73783404	26.76133533	26.73783404	26.82424266
H_2O Outlet Temperature	[°C]	31.46843603	31.52828191	31.46843603	31.6834273

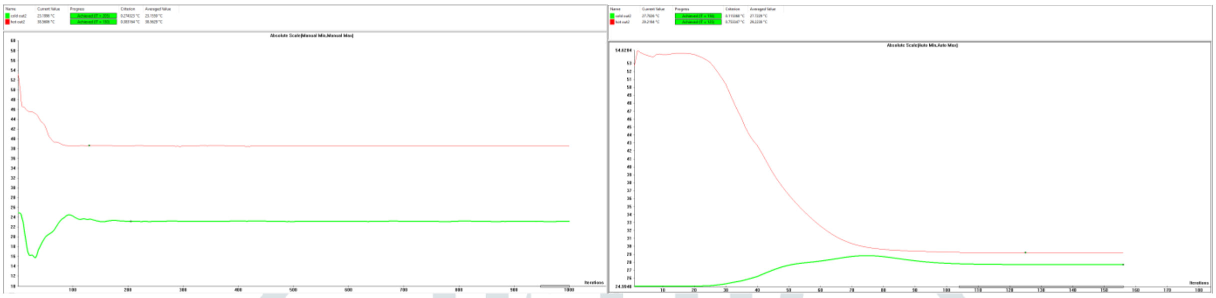

Figure 11 Convergence plot for U- tube Heat exchanger _ existing and proposed fluid conditions

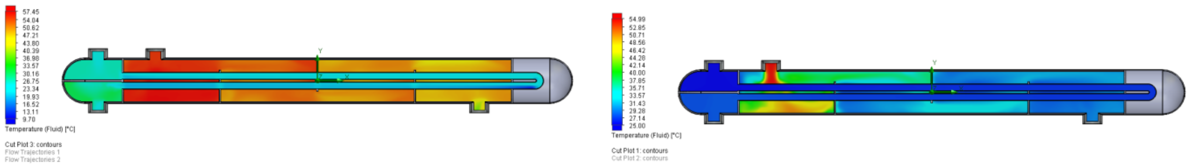

Figure 12 Temperature plot on tubes for U- tube Heat exchanger _ existing and proposed fluid conditions

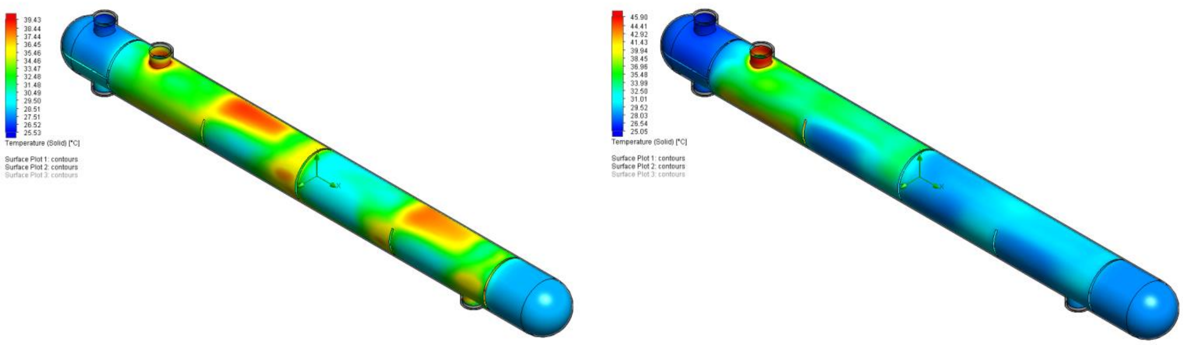

Figure 13 Surface temperature of shell for U- tube Heat exchanger _ existing and proposed fluid conditions

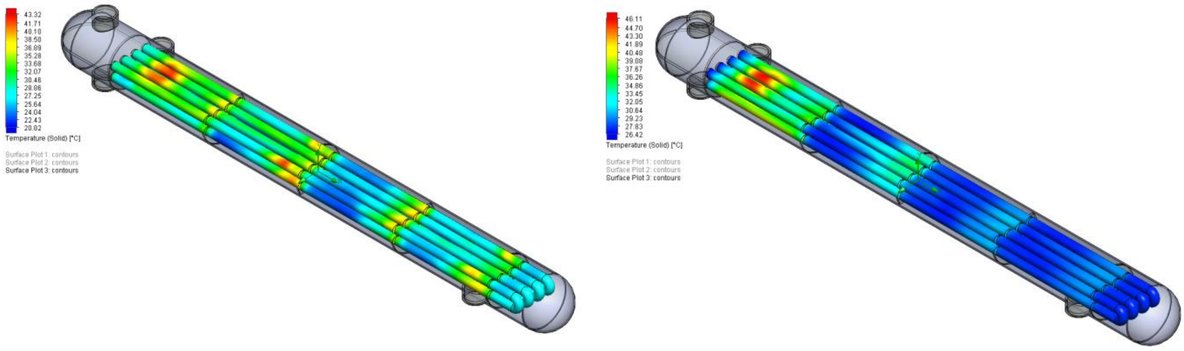

Figure 14 Surface temperature of tubes for U- tube Heat exchanger _ existing and proposed fluid conditions

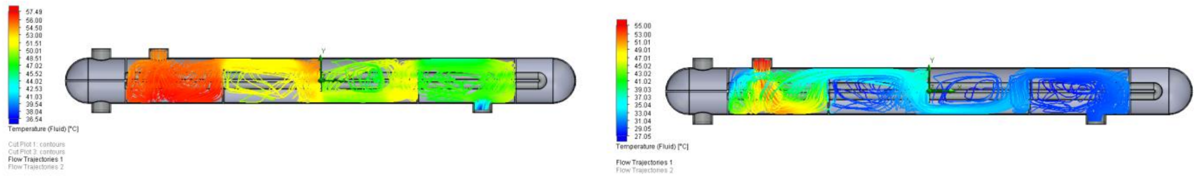

Figure 15 Fluid flow inside shell for U- tube Heat exchanger _ existing and proposed fluid conditions

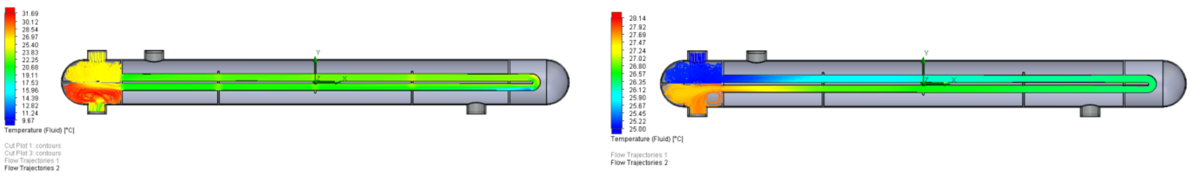

Figure 16 Fluid flow inside tubes for U- tube Heat exchanger _ existing and proposed fluid conditions

Table 5 Temperature results for U-tube Heat exchanger _ existing and fluid conditions

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
NH_4 Outlet Temperature	[°C]	38.56057496	38.56293632	38.55142398	38.57366928
H_2O Outlet Temperature	[°C]	23.19961106	23.15590864	23.11071565	23.19961106

Table 6 Temperature results for U-tube Heat exchanger _ proposed fluid conditions

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
Al_2O_3 Outlet Temperature	[°C]	29.21935477	29.22380711	29.20406832	29.23963026
H_2O Outlet Temperature	[°C]	27.70263317	27.72291545	27.70075269	27.8067006

The colored contour plots and the tabulations show that the proposed fluid's straight tube heat exchanger (Al_2O_3) has better thermal properties, and the degree of heating and cooling of the liquid is also found to be better under the proposed conditions.

Upon evaluation of the U-tube heat exchanger, the degree of heating and cooling is found to be unsatisfied under the new fluid conditions relative to the current straight tube heat exchanger fluids. But in terms of thermal properties including degree of heating and cooling, the tests of the u tube heat exchanger under the proposed fluid conditions are getting much better results than the other 3 cases.

IX. CONCLUSSION

In this project research, shell and tube heat exchanger output analysis against the u tube heat exchanger was carried out using the CFD devices. Initially the heat exchanger model was built using the solid works kit using the industry dimensional data obtained.

Using the solid works flow simulation kit, the models were then used for cfd analysis. The pre-processing work is performed according to the data from the industry, and the software has been designed to run the simulation. Results were then obtained using the software for analyzing prost, and stored as contour plots and table values.

The shell and tube heat exchanger with straight tube under the current ammonia fluid has the hot fluid outlet and cold fluid outlet at about 36 and 27 degrees Celsius respectively upon observation of the tests. Whereas the same under the state of fluid Al_2O_3 is around 31 and 26 degrees Celsius respectively. This shows that in Al_2O_3 condition the hot fluid is cooled up by 5 units higher. Cold water heating is lower in the Al_2O_3 compared to NH4, but this is not taken into account since the cold water outlet is sent to the cooling tower and there are no different functions outside the network.

On the analysis of results of u tube heat exchanger, the hot water outlet is around 29 degree Celsius in Al_2O_3 condition and around 38 degrees in NH_4 fluid condition. This shows that the proposed fluid is having better degree of cooling around 9 units higher than the existing fluid condition.

Hence in both the cases of straight and u tube heat exchangers, the system under the Al_2O_3 fluid is having better cooling performance and among the variants of the heat exchanger, the u tube type heat exchanger is having better performance results and this condition was suggested as better operating practice for beat performance.

X. ACKNOWLEDGMENT

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