

# MODELLING AND PERFORMANCE ANALYSIS OF HEAT EXCHANGER USING CFD TOOLS

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**Abstract :** Heat exchangers are used in thermal system to maintain the operating temperature of the working fluids. The most common type of heat exchangers found in industries are Shell and tube type heat exchangers. In this work, the performance analysis of shell and tube heat exchanger is done using the CFD tools under the boundary conditions collected from the industry. Then, to improve the efficiency of the system, the cooling liquid ammonia is replaced by TiO<sub>2</sub> and analyzed accordingly. Then the shell and tube heat exchanger is replaced by u tube heat exchanger and analyzed under same boundary conditions respectively. Then, the results are compared and it was found that, the application of TiO<sub>2</sub> is having better thermal efficiency.

**IndexTerms – Heat exchangers – CFD analysis – performance optimization – Nano fluids**

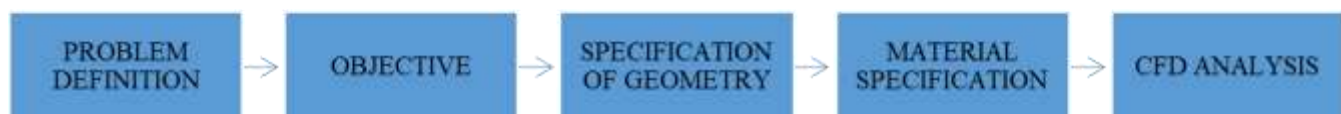
## I. INTRODUCTION

Heat exchangers are widely used in various thermal and thermal related industries for the purpose of maintaining a desired temperature in the system. Heat transfer occurs in many forms, one of this is convection, which is also known as convective heat transfer. This type of heat transfer is widely used in all types of heat exchangers. Among various types of heat exchangers, shell and tube type heat exchangers are widely used because of this simple construction and less maintenance. This type of heat exchangers run under parallel and counter flow modes.

In this project, a shell and tube heat exchanger is taken for analysis purpose. The model of the heat exchanger is done using solid works software and for future CFD analysis, the same package will be used, because this package is capable of integrating the model between the modelling and simulation. The datas for the simulation will be collected from a nearer dairy factory, as they use heat exchangers for maintaining the temperature in their system. Initially the existing setup will be subjected to CFD analysis and then the results are noted. Then, the working fluid is replaced from ammonia to titanium oxide hence attempting to increase the heat transfer from gas to liquid. Then the CFD results are tabulated and compared accordingly.

## II. METHODOLOGY

Methodology is the basic requirement for a project, because it defines the proper start and end conditions of the works to be done. Proper planning and execution of the workflow decides the successful completion of the project. The methodology of this project is as follows.



### 2.1 Problem Definition

Heat exchangers are widely used heat transfer devices and mainly used in food industries to preserve the foods and also to maintain the constant temperature at specified points of the travel of the liquids. The following is the layout of a typical food processing industry's heat transfer system.

In the below layout, the water from the reservoir enters the shell and tube heat exchanger as a cold water. Meanwhile in the other hand, a compressor sucks the ammonia from the accumulator and passes it through the pipes under constant pressure. 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 mixes with the hot fluid and as a result, heat transfer occurs. As a result, the water gets heated and sent to reservoir through pipes. During the travel, the water gets its work done here and there. On the other hand, the ammonia which was cooled, gets condensed and collected in the condenser tank, here the ammonia will be in liquid state and again pumped to accumulator unit where it gets ready to compress again by compressor, and this cycle repeats.

During this process, the heat transfer which occurs inside the exchanger is said to be not much efficient and not all the condensed ammonia is not collected at the tank. Some stay on the bottom layers of the shell. This in turn makes the shell corroded and makes the system failure.

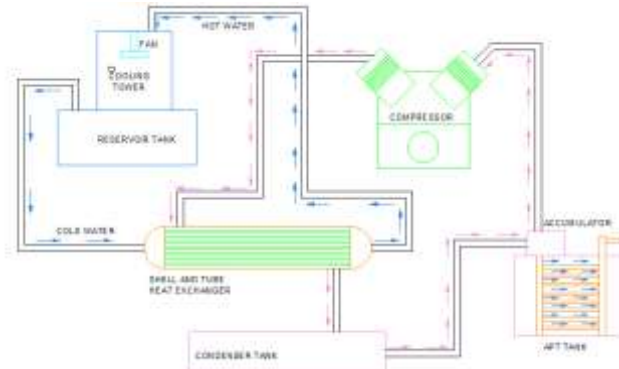


Figure 1 Thermal system of the industry

## 2.2 Objective

Based on the above mentioned problem, the objective was taken as to improve the condensation rate and to improve the amount of liquid ammonia collected in the tank. Also it was noted that, application of appropriate fluids can improve the heat transfer rate which results in increased efficiency of the system. With this approach, the objective of this project work included the heat transfer optimization of the shell and tube heat exchanger, by varying the coolant fluid and also by varying the geometry of the exchanger. CFD is used in this work to determine the heat transfer rate as well as temperature difference between the shell and tubes and inlet and outlet conditions of fluids respectively.

## 2.3 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

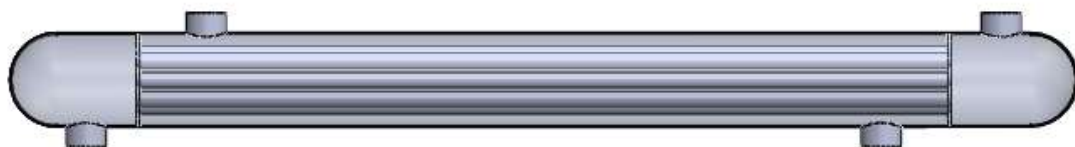


Figure 2 Shell and Tube type Heat Exchanger \_ existing type



Figure 3 U-Tube type Heat Exchanger \_ proposed type

## 2.4 Material Specification

Table 1 Material properties of NH<sub>4</sub> \_ 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 TiO<sub>2</sub> \_ proposed fluid

Property	Minimum Value (S.I.)	Maximum Value (S.I.)	Units (S.I.)
Density	3.97	4.05	Mg/m <sup>3</sup>
Energy Content	100	150	MJ/kg
Glass Temperature			K
Latent Heat of Fusion	820	930	kJ/kg
Maximum Service Temperature	1840	1910	K
Melting Point	2103	2123	K
Minimum Service Temperature	0		K
Specific Heat	683	697	J/kg.K
Thermal Conductivity	4.8	11.8	W/m.K
Thermal Expansion	8.4	11.8	10 <sup>-6</sup> /K
Breakdown Potential	2	12	MV/m
Dielectric Constant	10	85	
Resistivity	1.00E+19	1.00E+24	10 <sup>-8</sup> ohm.m

## 2.5 CFD Analysis

The CFD analysis was conducted under the following 3 steps.

- Pre-processing
- Solution
- Post-processing

The model importing and cleaning, meshing, boundary conditions and material property assigning are all done at the pre-processing stage. The solver settings and output settings and simulations are carried at the solution stage. The extraction of results from the saved database in the form of contour plots and tabulated values are done in the post-processing and this post-processing will be explained in the upcoming 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 = 55oC
- Inlet Cold fluid temperature = 25o C
- Outlet conditions = Environmental temperatures and pressure (Hot and Cold)

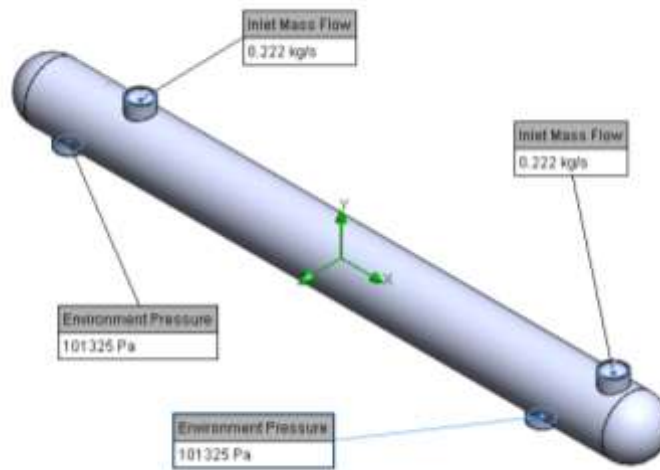


Figure 4 Boundary Conditions of the Heat exchanger used for CFD analysis

### III. 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.

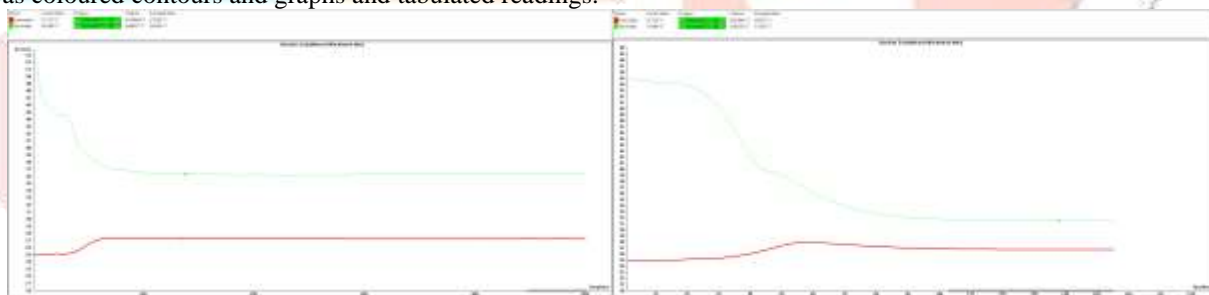


Figure 5 Convergence plot for Straight tube Heat exchanger \_ existing and proposed fluid conditions

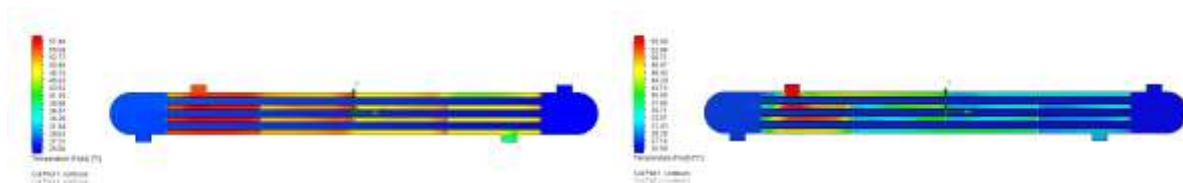


Figure 6 Temperature plot on tubes for Straight tube Heat exchanger \_ existing and proposed fluid conditions

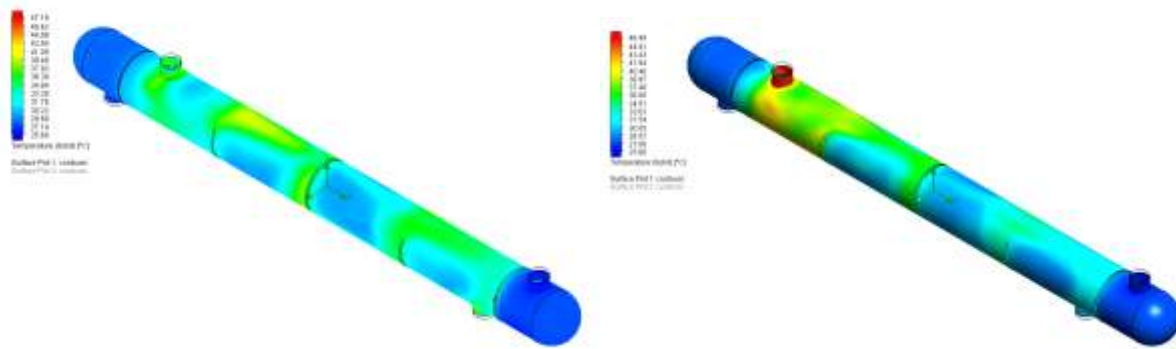


Figure 7 Surface temperature of shell for Straight tube Heat exchanger \_ existing and proposed fluid conditions

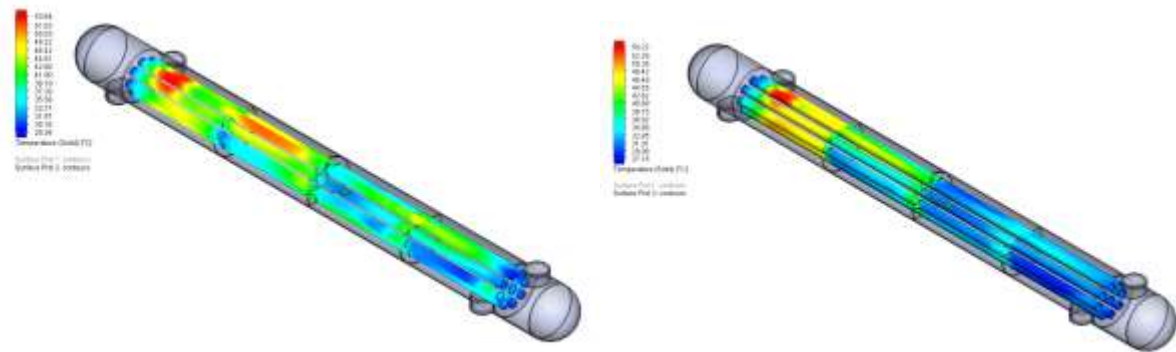


Figure 8 Surface temperature of tubes for Straight tube Heat exchanger \_ existing and proposed fluid conditions

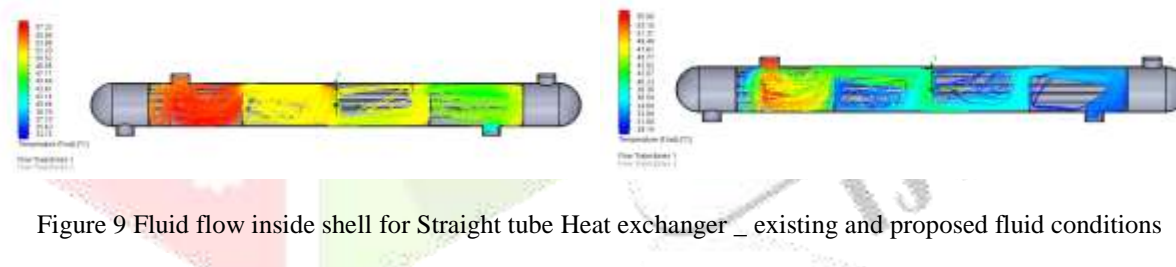


Figure 9 Fluid flow inside shell for Straight tube Heat exchanger \_ existing and proposed fluid conditions

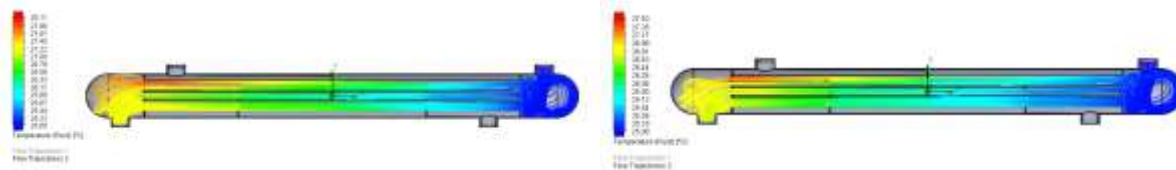


Figure 10 Fluid flow inside tubes for Straight tube Heat exchanger \_ existing and proposed fluid conditions

Table 3 Temperature results for Straight tube Heat exchanger \_ existing and fluid conditions

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
NH4 Outlet Temperature	[°C]	27.21715296	27.22949719	27.21715296	27.24292072
H2O Outlet Temperature	[°C]	36.28875563	36.28236837	36.25782921	36.32027699

Table 4 Temperature results for Straight tube Heat exchanger \_ proposed fluid conditions

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
TiO2 Outlet Temperature	[°C]	26.73783404	26.76133533	26.73783404	26.82424266
H2O Outlet Temperature	[°C]	31.46843603	31.52828191	31.46843603	31.6834273

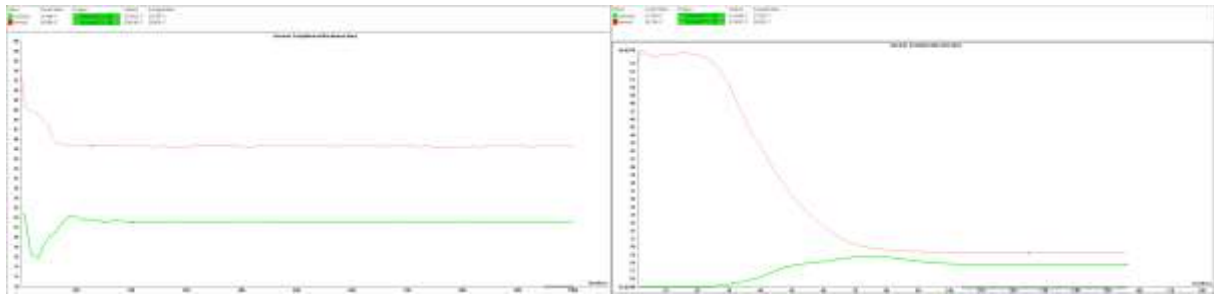


Figure 11 Convergence plot for U- tube Heat exchanger \_ existing and proposed fluid conditions

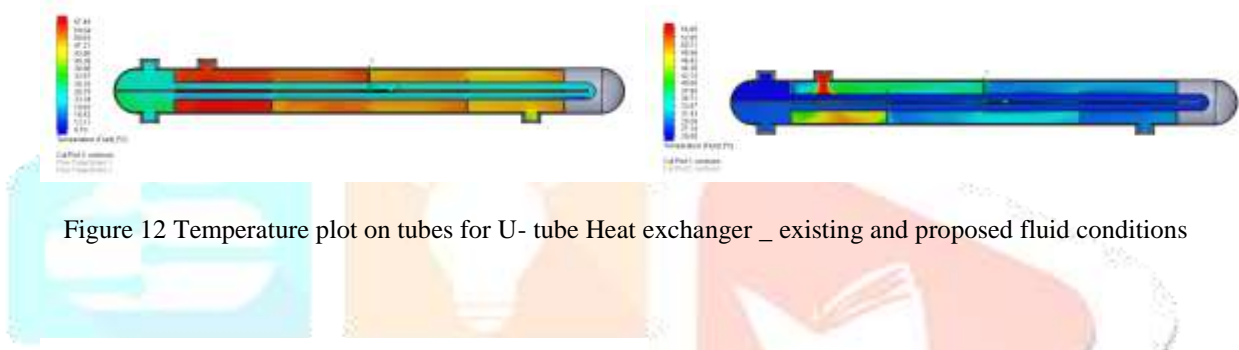


Figure 12 Temperature plot on tubes for U- tube Heat exchanger \_ existing and proposed fluid conditions

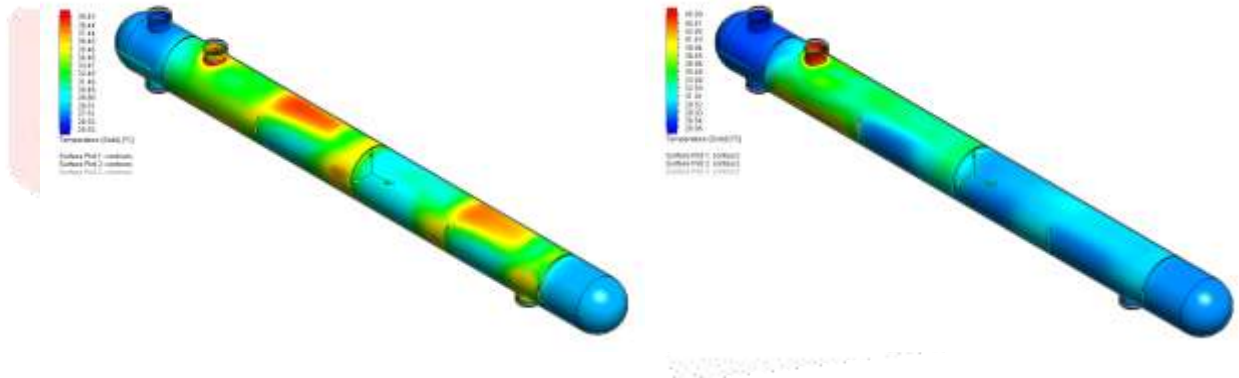


Figure 13 Surface temperature of shell for U- tube Heat exchanger \_ existing and proposed fluid conditions

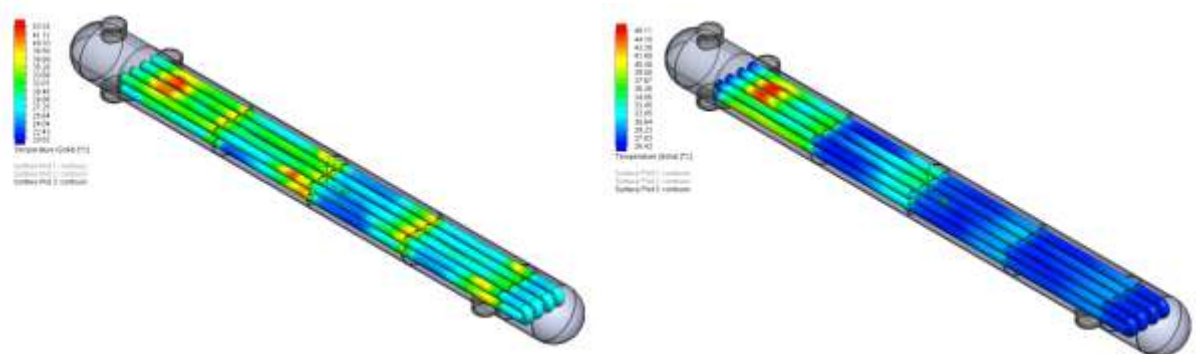


Figure 14 Surface temperature of tubes for U- tube Heat exchanger \_ existing and proposed fluid conditions

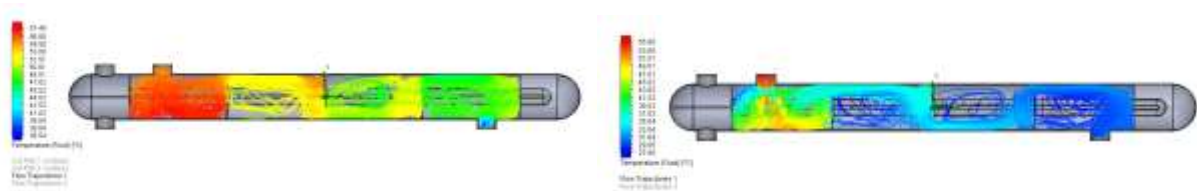


Figure 15 Fluid flow inside shell for U- tube Heat exchanger \_ existing and proposed fluid conditions

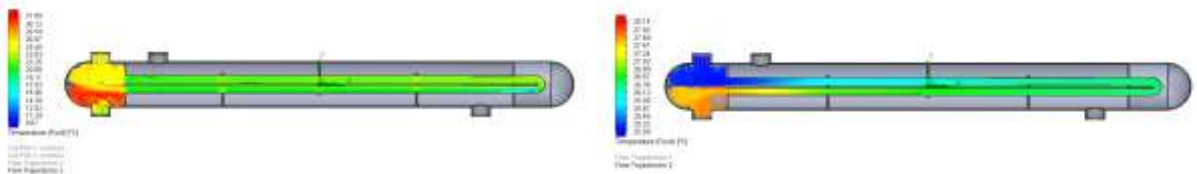


Figure 16 Fluid flow inside tubes for U- tube Heat exchanger \_ existing and proposed fluid conditions

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

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
NH4 Outlet Temperature	[°C]	38.56057496	38.56293632	38.55142398	38.57366928
H2O 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
TiO2 Outlet Temperature	[°C]	29.21935477	29.22380711	29.20406832	29.23963026
H2O Outlet Temperature	[°C]	27.70263317	27.72291545	27.70075269	27.8067006

The coloured contour plots and the tabulations shows that the straight tube heat exchanger under the proposed fluid (TiO2) is having better thermal properties and the degree of heating and degree of cooling of the liquid are also found to be better in the proposed conditions.

On observation of U tube heat exchanger, the degree of heating and cooling under the existing fluid conditions are found to be not satisfied compared to the existing fluid of straight tube heat exchanger. But the results of the u tube heat exchanger under the proposed fluid conditions are having much better results than the other 3 cases in terms of thermal properties like degree of heating and cooling.

#### IV. CONCLUSION

Performance analysis of the shell and tube heat exchanger versus the u tube heat exchanger was conducted in this project work using the CFD tools. Initially the model of the heat exchangers were built using the solid works package using the dimensional data collected from the industry.

Then the models were used for the cfd analysis using the solid works flow simulation package. The pre-processing works are done as per the industry data and the model was set to run the simulation. Then results were retrieved using the post processing tools and saved as contour plots and tabulated values.

On observation of the results, the shell and tube heat exchanger with straight tube under the existing ammonia fluid is having the hot fluid outlet and cold fluid outlet around 36 and 27 degree Celsius respectively. Whereas the same under the TiO2 fluid condition is having around 31 and 26 degree Celsius respectively. This shows that the hot fluid gets cooled by 5 units higher in the TiO2 condition. The heating of cold water is lesser in the TiO2 when compared to NH4, but this is not taken into account as per the industry requirements, because the cold water outlet is sent to cooling tower and it has no specific functions to do outside the system.

On the analysis of results of u tube heat exchanger, the hot water outlet is around 29 degree Celsius in TiO2 condition and around 38 degrees in NH4 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 TiO<sub>2</sub> 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 heat performance.

#### V. ACKNOWLEDGMENT

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#### REFERENCES

- [1] Vindhya vasinay prasad dubey, raj rajat verma, piyush shanker and a.k.srivastava, “performance analysis of shell & tube type heat exchanger under the effect of varied operating conditions”, journal of mechanical and civil engineering (iosr-jmce), volume 11, issue 3 ver. Vi (may- jun. 2014), pp 08-17.
- [2] Vikas kumar, d. Gangacharyulu, parlapalli ms rao and r. S. Barve, “cfD analysis of cross flow air to air tube type heat exchanger”.
- [3] Avinash D Jadhav, Tushar A Koli, “Cfd Analysis Of Shell And Tube Heat Exchanger To Study The Effect Of Baffle Cut On The Pressure Drop”, International Journal Of Research In Aeronautical And Mechanical Engineering, 2321-3051
- [4] Hetal Kotwal, D.S Patel, “Cfd Analysis Of Shell And Tube Heat Exchanger- A Review”, International Journal Of Engineering Science And Innovative Technology, Volume 2, Issue 2, March 2013
- [5] Alok vyas, mr. Prashant sharma, “an experimental analysis study to improve performance of tubular heat exchangers”, alok vyas et al int. Journal of engineering research and applications, vol. 3, issue 6, nov-dec 2013, pp.1804-1809.
- [6] Apu Roy, D.H.Das, “Cfd Analysis Of A Shell And Finned Tube Heat Exchanger For Waste Heat Recovery Applications”, International Journal Of Mechanical & Industrial Engineering, Volume-1 Issue-1, 2011

