# Design and Analysis of Shell and Tube Heat Exchanger with Inclined Baffles

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***Abstract*— Heat exchangers are apparatus that transfers heat from one medium to another. The proper design, process and keeping of heat exchangers will make the process energy capable and minimize energy losses. Among used in different types of heat exchangers. But shell and tube heat exchangers have been commonly used in industries. The baffles are mostly used in primarily, shell and tube heat exchangers for inducing cross flow over the tubes, and as a result, improving heat transfer performance. The traditional shell and tube heat exchanger with segmental baffles have many disadvantages, such as high pressure go down, high heat transfer efficiency, harmful vibration caused by the shell-side flow which is normal to tube bundles. Therefore, a shell and tubular heat exchanger with different design style of baffle (inclined type $20^0$) used to achieve higher heat transfer efficiency and lower pressure drop. In this project various method of improving the heat transfer performance has been carried out. The mathematical calculation is done by Kern method. The CFD analysis has been carried out between two model of shell and tube heat exchanger one with segmental baffles and another with inclined baffles. The heat transfer performance of shell and tube heat exchanger is increased and reduced pressure drop is achieved by segmental baffle is replaced with inclined baffles.**

***Index Terms*— Shell and tube heat exchanger, baffles.**

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## I. Introduction

### 1.1 Heat Exchanger

Heat exchangers are apparatus that transfers heat from one medium to another. Mostly Shell-and-tube heat exchangers are commonly used in many industries and applications, simple manufacture and adaptability to different operating conditions. Their sturdiness and structure make them well suitable for high pressure operations. The baffles are mainly used in shell and tube heat exchangers for inducing cross flow over the tubes, and as a result, improving heat transfer performance.

### 1.2 Computational Fluid Dynamics

CFD is a computationally-base design and analysis method. CFD software analysis the flow of gases and liquids, heat and mass transfer, moving bodies, multiphase physics, chemical reaction, fluid-structure interaction and acoustics through computer modeling. This software can also build a virtual prototype of the system or device before can be apply to actual-world physics and chemistry to the model, and the software will give with images and data, which expect the performance of that design. Computational fluid dynamics (CFD) is useful in a wide multiplicity of applications and use in industry. The imitation is performed by the FLUENT software. CFD is one of the branches of fluid mechanics that uses numerical methods and algorithm can be used to solve and analyse problems that involve fluid flows and also simulate the flow over a piping, vehicle or machinery. Computers are used to perform the millions of calculations necessary to simulate the interaction of fluids and gases with the difficult.

### 1.3 Shell and Tube Heat Exchanger

Shell and tube heat exchangers consist of a string of tubes. One set of these tubes contains the fluid that should be either heated or cooled. The second fluid runs more the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat essential. A set of tubes is called the tube bundle and can be made up of several types of tubes: simple, longitudinally finned, etc. Shell and tube heat exchangers are typically used for high-pressure applications (with pressures larger than 30 bar and temperatures greater than 260 °C). This is because the shell and tube heat exchangers are robust due to their shape. Surface condensers in power plants are often single pass straight-tube heat exchangers .Two and four pass designs are ordinary because the fluid can enter and exit on the same side.

#### 1.3.1 Straight Tube Heat Exchanger

There can be several variations on the shell and tube design. Typically, the ends of each tube are connected to plenums (occasionally called water boxes) throughout holes in tube sheets. The tubes may be straight or bent in the shape of a U, called U-tubes.

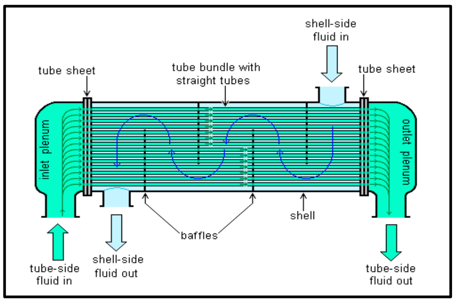


**Fig.1 Single pass straight tube heat exchanger**

### 1.4 BAFFLES

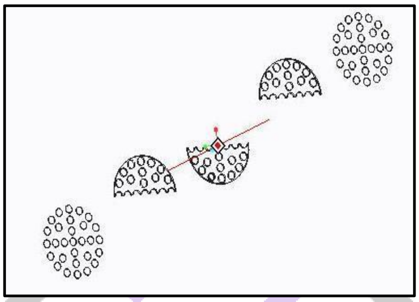

**Fig.2 Segmental baffles**

Baffles are installed in shell and tube heat exchanger on the shell side to give a higher heat transfer rate due to turbulence and to support the tubes thus sinking the chance of damage due to vibration. The segmental baffle is used in this paper. The segmental baffle is used because of its easy in construction. The segmental baffles also provide better cross flow.

### 1.5 TUBES AND TUBE BUNDLES

The tube bundle contains tubes, tie rods, baffles and tube sheet. There are totally 6 tubes which are arranged in each three tube are in parallel and horizontal direction.

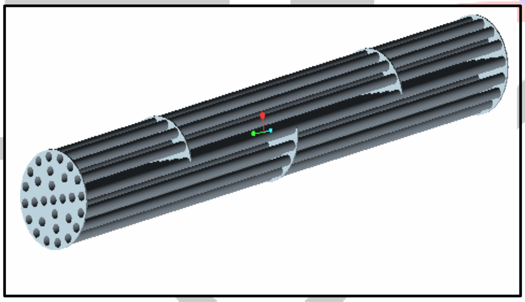

**Fig.3 Tube bundle with baffles and tube sheet**

### 1.6 SHELL

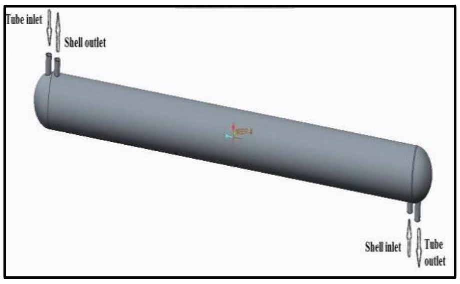


**Fig.4 Shell**

The external shell is cylindrical and its inner diameter equal to the tube sheet and baffle diameter. . The shell side fluid and tube side fluid is passed in opposite direction in order to obtain higher heat transfer rate.

## II. Literature Survey

### 2.1 Studies related to baffle

This paper investigated the local heat transfer and pressure fall on the shell side of shell and tube heat exchanger with segmental baffles. After his investigation he proposed that increasing baffle spacing can increase the heat transfer coefficient in the whole baffle compartment both due to the decline of the percentage of the leakage stream and due to the higher flow velocity throughout the baffle opening. The local heat transfer coefficient distribution at an individual tube is slightly affected by the baffle. The pressure drop coefficient for long baffle spacing is higher than for a short one [1]. This paper investigated a conventional shell-and-tube heat exchanger, fluid contacts with tube tubes due to the stagnation portions. From their investigation they concluded that the shell-and-tube heat exchanger with spiral baffle plates improves heat exchanger performance because rotational flow in the shell caused by the curved baffle plates eliminates the stagnation area of the conventional heat exchanger. Spiral baffle plates introduce vortices in the shell side flow field and enhance heat transfer between shell and tube side fluids, even though it increases pressure drop [2]. In this paper they designed a shell-and-tube heat exchanger with new type of baffles, is designed, fabricated and tested. The experimental investigation for the planned model and the original segmental baffle heat exchanger are conducted. By properly designing FB-STHX the heat transfer and pressure reduce performance can be improved relative to the traditional SG-STHX [3]. To validate the CFD algorithm the experiment was conducted on an existing single pass oppose flow shell and tube heat exchanger. The optimum values obtained are baffle angle 5°, baffle cut 25%. Numerical simulations were carried out to study the impacts of various baffle inclination angles on fluid flow and heat transfer of heat exchangers with helical baffles. The average Nusselt number increases with the increase of the baffle inclination angle $\alpha$ when $\alpha$<30 ◦. Whereas, the average Nusselt number decreases with the increase of the baffle inclination angle when $\alpha$>30◦ [4].

### 2.2 Summary of Literature Review

- Among various types of heat exchangers, shell and tube heat exchangers are used in many applications.
- The STHX with segmental baffles is mostly used because of its ease in construction and greater advantage in maintenance.
- The optimum baffle spacing is to be maintained for increasing heat transfer efficiency and reducing the pressure drop.

## III. Geometrical Parameters

### 3.1 Tube bundle and tube sheet specification

- Material : Copper
- Tube internal dia : 17 mm
- Tube external dia : 19 mm
- Tube length : 1910 mm
- No. of tubes : 6
- Tube sheet dia : 175 mm
- Tube sheet thickness : 7 mm

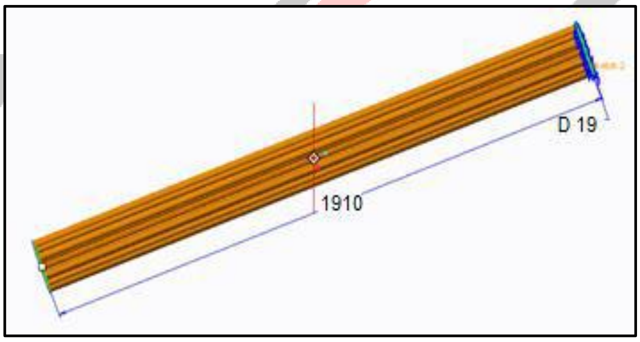


**Fig.5 Tube bundle specification**

### 3.2 Baffle specification

- Material : Copper
- Baffle diameter : 175 mm
- Baffle thickness : 7 mm
- No. of baffles : 5
- Baffle spacing : 369 mm
- Baffle type : inclined

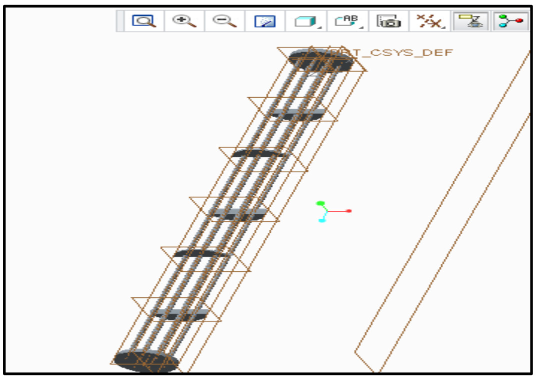

**Fig.6 tube bundle**

### 3.3 Shell Specification

- Material : Carbon steel
- Shell outer diameter : 180 mm
- Shell inner diameter : 175 mm
- Shell length : 1910 mm
- Shell fluid inlet and outlet
- Internal diameter : 25 mm
- External diameter : 30 mm

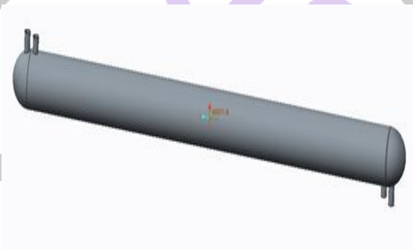

**Fig.7 Shell**

## IV. Thermo Physical Parameters

### 4.1 Properties of Carbon Steel

- Specific heat capacity (Cp) : 502.48001 J/kgK
- Density (ρ) : 8030 kg/$m^3$
- Thermal conductivity(k) : 16.27 W/mK

### 4.2 Properties of Copper

- Specific heat capacity (Cp) : 381 J/kgK
- Density (ρ) : 8978 kg/m3
- Thermal conductivity(k) : 387.6 W/mK

### 4.3 Properties of Water

- Shell side fluid : Water
- Temperature : 100ºC
- Velocity : 1 m/s
- Tube side fluid : Water
- Temperature : 30ºC
- Velocity : 0.75 m/s

### 4.4 Mathematical Selecting a baffle spacing and pressure drop

$$N_B = \frac{L_S}{L_B + T_B}$$

THE NUMBER OF BAFFLE - ($N_B$)
BAFFLE SPACING (M) - ($L_B$)
SHELL LENGTH (M) - ($L_S$)
THICKNESS OF BAFFLE (M) -($T_B$)

$$5 = \frac{1880}{L_B + 7}$$

$$= 369 \text{ M}$$

$$S_S = \frac{D_S P_D L_B}{P_T}(m^2)$$

Ds = Shell internal diameter (m)
PT = Tube pitch (triangular) (m)
PD = Gap between the tubes (m)
LB = Baffle spacing (m)

$$Re = \frac{D_e G_s}{\mu_f}$$

$$\Pr = \left(\frac{C_p \mu}{k}\right)_f$$

$$D_e = \frac{4(P_T^2 - \pi D_O^2/4)}{\pi D_o}(m)$$

$$G_s = \frac{\dot{m}}{S_S}(Kg/m^2 s)$$

Re = Reynolds number
Pr = Prandtl number
m = Mass flow rate (kg/s)
De = Effective diameter (m)
F = Friction factor
µ = Viscosity (Pa s
k = Thermal conductivity (kJ/smK)
CP = Heat capacity (kJ/kgK)
Do = Tube outside diameter (m)

**4.5 CALCULATED THE HEAT CO EFFICIENT BY USING FORMULA**

- $Q = FUA(\Delta T)$ (REFER PAGE NO-152 HMT DATA BOOK)
- $(\Delta T) = \frac{(T1-t2)-(T2-t1)}{\ln\left(\frac{T1-t2}{T2-t1}\right)}$ (REFER PAGE NO-152 HMT DATA BOOK)
- $A = \frac{\pi}{4} * D^2$
- FRACTION FACTOR (F) = R.P. (REFER PAGE NO-159 HMT DATA BOOK)
- $R = \frac{T1-T2}{t2-t1}$ (REFER PAGE NO-159 HMT DATA BOOK)
- $P = \frac{t2-t1}{T1-t1}$ (REFER PAGE NO-159 HMT DATA BOOK)
- HEAT CO EFFICIEND (U) (REFER PAGE NO-156 HMT DATA BOOK)

## V. MODELLING

The geometric model is created using Creo Parametric 2.0. The pattern of tube arrangement in the tube bundle is first modelled in Creo Parametric. Then the tube is extruded for the length of 1910 mm.

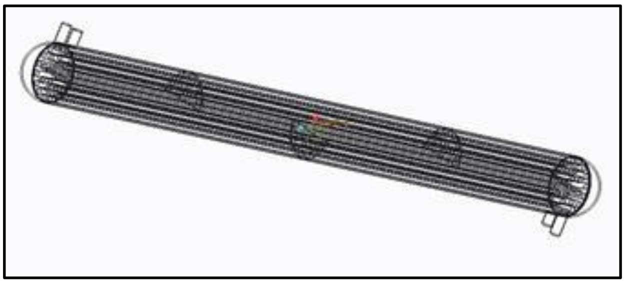

**Fig.8 Shell**

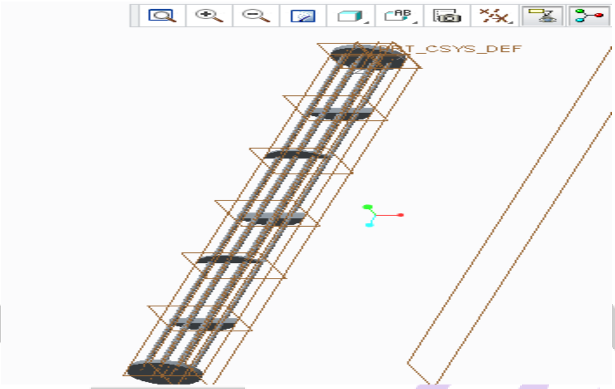

**Fig.9 Tube bundle**

### 5.1 MESH GENERATION

As the geometry is more complex the meshing is done by Hyper Mesh 11.0 software. .As the geometry has some complicated and skewed surfaces the tetrahedral mesh is use and the volume meshed.

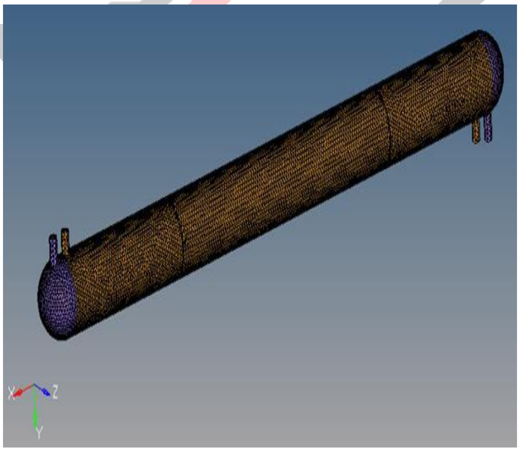

**Fig.10 Meshing**

## VI. ANALYZING

### 6.1 STRAIGHT BAFFLE

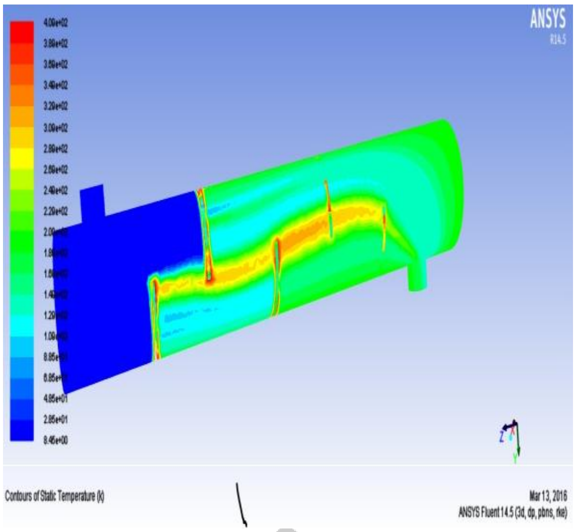


**Fig.11 Temperature**

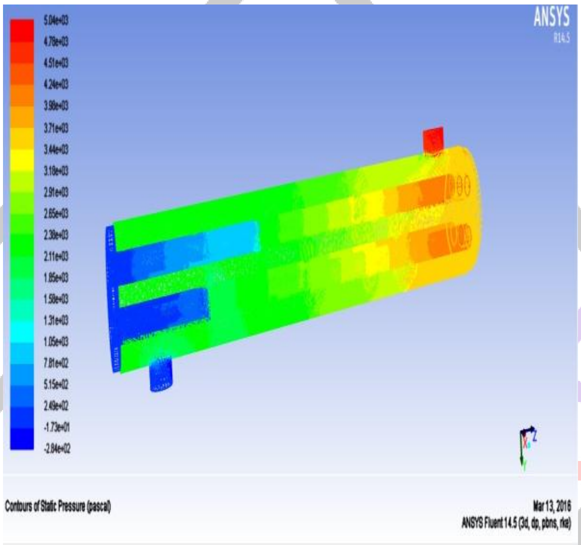


**Fig.12 Pressure**

### 6.2 INCLINED BAFFLE

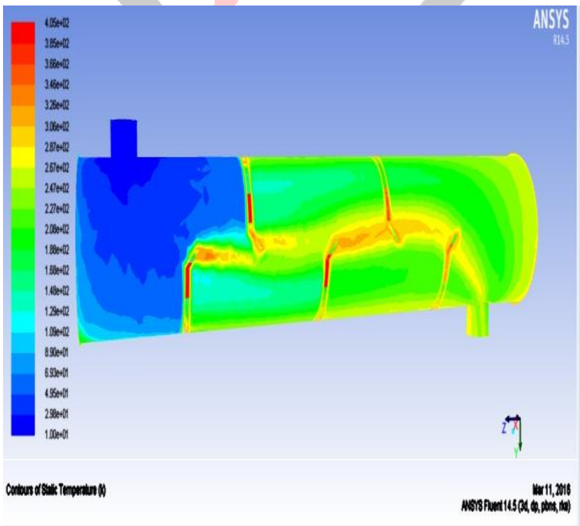


**Fig.13 Temperature**

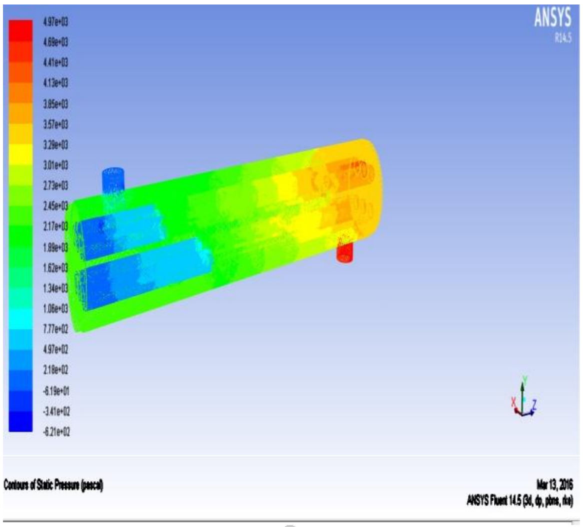


**Fig.14 Pressure**

### 6.3 Solver Setup

FLUENT 6.2 are used as the solver for this case.

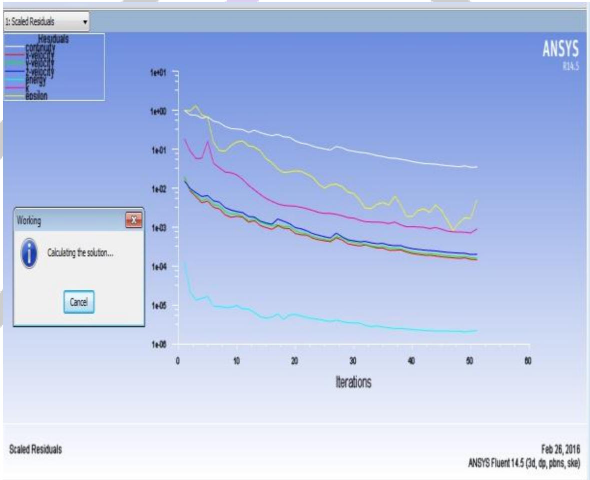


**Fig.15 Solver Setup**

## VII. Results

### 7.1 Heat Transfer co-efficient

**HEAT TRANSFER *(W/M-2 K)***

| STRAIGHT BAFFLES (W/M²K) | INCLINED BAFFLES (W/M²K) |
|---|---|
| 508.22 | 580.72 |

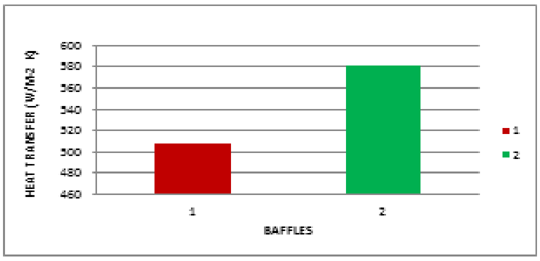


**Fig.16 Straight Vs inclined baffles (Heat Transfer)**

As we compared with both result, inclined baffles heat transfer co efficient is greater (72.5 $w/m^2k$) then straight baffle heat transfer co efficient.

### 7.2 Pressure Drop

**PRESSURE DROP (PASCAL)**

| STRAIGHT BAFFLES (PASCAL) | INCLINED BAFFLES (PASCAL) |
|---|---|
| 5040 | 4970 |

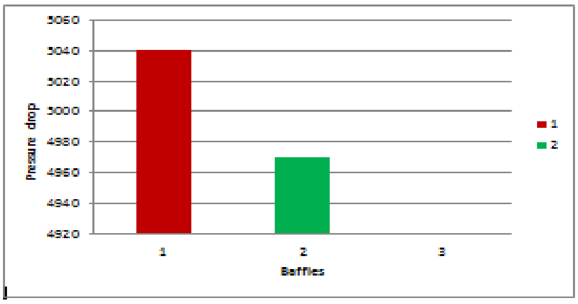


**Fig.17 Straight Vs inclined baffles (pressure drop)**

As we compared with both result, inclined baffles pressure drop is less (70 Pascal) than straight baffles pressure drop.

## Conclusion

- Number of method using to increasing the heat transfer coefficient, by used to kern method.
- CFD used to analysis the two type of heat exchanger.(inclined & straight baffles)
- From the result, increasing heat transfer (9-12 %) and slightly reduced pressure drop (1.3-2.5 %).

## References

[1] Huadong Li and Volkar Kottke (1997), "Effect of baffle spacing on pressure go down and local heat transfer in shell and tube heat exchanger", PH: S0017-9310 (97) 00201-9

[2] Young-Seok Son and Jee-Young Shin (2001), "Performance of a shell and tube heat exchanger with spiral baffle plates", KSME International Journal, Vol. 15, No. 11, pp. 1555-1562.

[3] Yingshuang Wang, Zhichun Liu, Suyi Huang, Wei Liu and Weiwei Li (2011), "Experimental investigation of shell and tube heat exchanger with a new type of baffles", Heat and mass transfer, Vol. 47, pp. 833-839. 6] R Cabello, R Llopis, D Sanchez and E Torrella (2010), "A simplified model for shell and tube heat exchanger", Applied thermal engineering (Elsevier science direct), Vol. 47, pp. 833-839.

[4] Simin Wang, Jian Wen and Yanzhong Li (2009), "An experimental investigation of heat transfer enhancement for a shell and tube heat exchanger", Applied thermal engineering (Elsevier science direct), Vol. 29, pp. 2433-2438.