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Computational Fluid Dynamics Analysis of Single Pass Shell & Tube Heat Exchanger with Different Orientation of Baffles and Without Baffles

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Abstract : - In this specific project an endeavor is design for CFD evaluation of Single Pass Shell & Tube Heat Exchanger with Different Orientation of Baffles and Without Baffles with counter flow of fluid. In order to research the performance of the heat exchanger, hot fluid was designed to flow inside the seven tubes and cold fluid flows through outer pipe & tube material using Copper as well as Brass & Shell Material using Carbon Steel. The baffles utilized in heat exchanger are usually segmental baffles cut of 25%. The introduction of baffles, force the fluid to have a turbulent flow, thus improving the heat transfer rate. The outcomes of heat transfer rate for flow of fluid with vertical segmental baffle inside heat exchanger are in comparison with the heat exchanger without having baffles. The result of heat transfer rate & pressure drop for flow of fluid for 0^0 baffles is also compared with baffle at 30^0 orientations. The flow of hot fluids at different Reynolds number will carry out having fluid velocity of 1 m /s, 2 m /s and 3 m /s & the flow of cold fluids at Reynolds number will carry out having fluid velocity of 1 m /s. The deviation of heat transfer coefficient & pressure drop at different baffle orientations as been carried out by means of Fluent 14.5 simulation.

STHX is an indirect contact type heat exchange because it is made up of a series of tubes, through which one of the fluids goes. They are traditionally used in oil refineries, chemical plants, petrochemical plants, natural fuel processing, air-conditioning, refrigeration as well as automotive applications. Computational Fluid Dynamics (CFD) can very helpful to obtain visualize the actual flow as well as temperature fields with in the shell side can simplify the assessment of the weaknesses. Different turbulence models available in general purpose commercial CFD tools likes k-ε, K-ω as well as K-ω SST models. This literature review concentrates on the value and effectiveness of k-ε model in CFD evaluation and simulation.

Keywords: - Heat Transfer Coefficient, Shell-and-Tube Heat exchanger, CFD, Un-baffled, Baffle inclination angle, Segmental Baffle, Reduced Pressure Drop.

I. INTRODUCTION

Heat exchangers have always been an important part to the life-cycle and operations of many systems. A heat exchanger is can be a device created for effective heat transfer from one medium to different in order to carry and process energy. Typically one medium is cooled while the other will be heated. They're widely utilized in petroleum refineries, chemical plants, petrochemical plants, natural gas processing, Air conditioning, refrigeration and also automotive applications. One popular example of the heat exchanger will be the radiator within a car, in which it transfers heat from the water (hot engine-cooling fluid) in the radiator to the air passing through the radiator. There are two main kinds of heat exchangers:

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Direct contact heat exchanger in which both media between which heat is exchanged are in direct contact with each other.

Indirect contact heat exchanger where both media are separated by a wall through which heat is transferred so that they never mix. Shell and tube type heat exchanger is an indirect contact type heat exchanger as it consists of a series connected with tubes, through which one of the fluids runs. The shell can be a container for the shell fluid. Usually, it's cylindrical in shape with the circular cross section, although shells of various shapes are used in particular applications. With this particular study E shell is considered, which a one pass shell is generally. E shell is the most widely used because of its low price and simplicity, and has got the highest log mean temperature- difference (LMTD) modification factor. Although the tubes may have single or multiple passes, there is usually one pass on the shell side, while the other fluid flows inside the shell over the tubes to be heated or cooled. STHX in various sizes are widely used in industrial operations and energy conversion systems. The best possible thermal design of the STHX involves the consideration of many interacting design parameters which can be summarized as follows:

Process

1. Process fluid assignments to shell side or tube side.
2. Selection of stream temperature specifications.
3. Setting shell side and tube side pressure drop design limits.
4. Setting shell side as well as tube side velocity restrictions.

Mechanical

1. Selection of heat exchanger TEMA design and number of passes.
2. Specification of tube parameters - size, layout, pitch and material.
3. Setting upper and lower design limits on tube length.
4. Specification of shell side parameters – materials, baffles cut, baffle spacing and clearances.
5. Setting upper as well as lower design limits in shell diameter, baffle cut and baffle spacing.

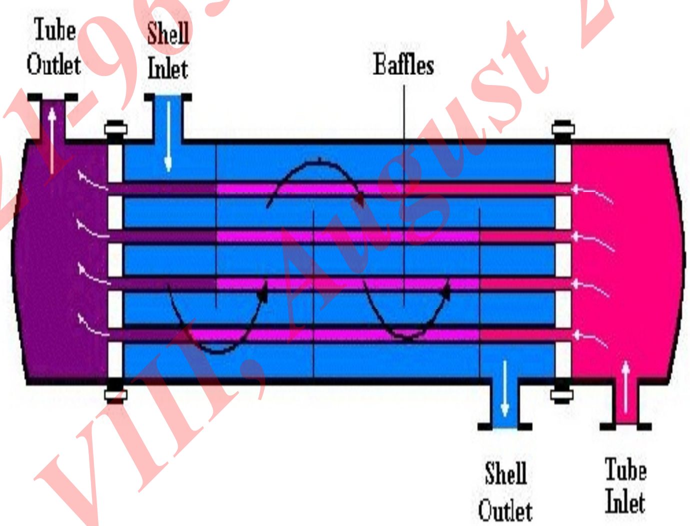

Fig.1 Shell and tube heat exchanger along with baffles plate.

Shell-and-tube heat exchangers are designed and fabricated based on the standards of the Tubular Exchanger Manufacturers Association (TEMA). Heat exchangers are utilized in many engineering purposes like energy generation, waste heat recuperation, manufacturing sector, air-conditioning, refrigeration, living space applications, petrochemical sectors etc. Use of segmental baffles in a Heat Exchanger result in high pressure drop which is undesirable as pumping costs are directly proportional to the pressure drop inside a Heat Exchanger. Therefore, lower pressure drop indicates the lower operating and capital costs

- . Application of Shell & Tube Heat Exchanger:-

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Table 1.1, Heat Exchanger Applications in Different Industries.

Industries	Applications
Food and Beverages	Ovens, cookers, Food processing and also pre-heating, Milk pasteurization, beer cooling and pasteurization, fruit juices and syrup pasteurization, cooling or chilling the final product to Desired temperatures.
Petroleum	Brine cooling, crude oil pre-heating, crude oil heat treatment, Fluid interchanger cooling, acid gas condenser.
Hydro carbon processing	Preheating of methanol, liquid hydrocarbon product cooling, feed pre-heaters, Recovery or removal of carbon dioxide, Production of ammonia.
Polymer	Production associated with polypropylene, Reactor jacket cooling for that Production of polyvinyl chloride.
Pharmaceutical	Purification of water and also steam, For point of use cooling on Water For Injection ring.
Automotive	Pickling, Rinsing, Priming, as well as Painting.
Power	Cooling circuit, Radiators, Essential oil coolers, air conditioners and Heaters, energy recovery.
Marine	Marine cooling systems, Clean water distiller, Diesel fuel Pre-heating, central cooling, Cooling of lubrication oil.

II. COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics (CFD) is the application of computers and also numerical techniques to solve complications involving fluid flow. CFD have been successfully applied in several areas of fluid mechanics. These consist of aerodynamics of cars as well as aircraft, hydrodynamics of ships, flow through pumps and turbines, combustion as well as heat transfer, chemical engineering. Applications within civil engineering include wind loading, vibration regarding structures, wind and wave energy, ventilation, fire, explosion hazards, dispersal of pollution, wave loading on coastal and offshore structures, hydraulic structures for example weirs as well as spillways, sediment transport. More specialist CFD applications include ocean currents, climate forecasting, plasma physics, blood flow and heat transfer around electronic circuitry.

This variety of applications is extremely broad and also involves a variety of fluid phenomena. In particular, the CFD techniques useful for high-speed aerodynamics (where compressibility will be significant but viscous as well as turbulent effects are often unimportant) are very different from those used to solve the incompressible, turbulent flows typical of mechanical and civil engineering. Although a few elements of this course are widely applicable, the focus is going to be on simulating viscous, incompressible flow through the finite-volume method.

- Stages in a CFD Simulation:-

The primary stages within a CFD simulation are:

- ✓ Pre-processor: Creating the model:-
  - Identify the method or equipment to become evaluated.
  - Represent the actual geometry of interest utilizing CAD tools.
  - Use the actual CAD representation to produce a volume flow domain across the equipment that contains the essential flow phenomena.
  - Create the computational mesh within the flow domain.
- ✓ Solver:-

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- Identify and also apply conditions in the domain boundary.
- Solve the actual governing equations for the computational mesh using evaluation software.

✓ Post processor: Interpreting the outcomes:-

- Post-process the actual completed ways of highlight results.
- Interpret the actual prediction to find out design iterations as well as possible remedies, if required.

III. LITERATURE REVIEW

E.Salehi et al. [1] evaluate the shell-side stream of STHX utilizing experimental as well as theoretical techniques. Experimental as well as numerical results are compared over a wide range of Reynolds numbers (1,000 t o 1,000,000). The most crucial results of this research are the following:

- Comparison associated with temperature profile of exchanger, along with and without baffles, shows that baffles possess the vital role in heat transfer rate.
- The outcomes also show how the effect associated with changing the quantity of baffles will be more crucial than various the heights of baffles with regard to heat transfer rate in the shell.
- Increasing Reynolds number in shell-side leads to the improve of heat transfer rate.
- Reynolds number could be increased with the addition of the quantity of baffles easier and along with less cost as compared with increasing the actual inlet velocity on the fluid.

D.P.Naik et al. [2] has a assessment associated with counter flow shell & tube heat exchanger by means of entropy era minimization technique. The design variables which can be used to the shell & tube heat exchanger are usually tube inside diameter, tube outside diameter, number of tubes, baffle spacing as well as tube pitch etc. The analyses of those design parameters are very important to the overall performance of shell & tube heat exchanger. Shell & tube heat exchanger overall performance has increased significantly by means of minimization of entropy generation number considering the various design variables. For the reason that mass flow rate associated with shell side fluid will increase, the entropy era number increases. Therefore we can easily reduce this entropy era number by means of reducing this mass flow rate of cold fluid by optimization. If we change tube side area heat exchanger effectiveness also change.

Kevin M. Lunsford et al. [3] possesses analyzed to improve the heat exchanger effectiveness & advised increasing heat exchanger performance via a logical number of steps. The initial step considers when the exchanger can be initially working correctly. The 2nd step looks at increasing pressure drop if easily obtainable in exchangers with single-phase heat transfer. Increased velocity leads to higher heat transfer coefficients, which can be sufficient to enhance performance. Next, a crucial evaluation in the estimated fouling factors might be of interest. Heat exchanger performance could be increased using periodic cleaning & fewer conservative fouling factors. Finally, for several conditions, it might be feasible to contemplate enhanced heat transfer by using finned tubes, inserts, twisted tubes, or maybe modified baffles.

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M.A.Mehrabian et al. [4] provides the comparison associated with experimental data with estimations of regular correlations for that overall heat transfer characteristics of an double pipe heat exchanger and concluded that when heat comes to this inner tube stream by means of an immersion heaters. The overall heat transfer coefficients are usually inferred in the measured data. The heat transfer coefficient from the inner tube flow (circular cross section) will be calculated while using the standard correlations. The heat transfer coefficient from the outer tube flow (annular cross section) is usually then deduced. Higher heat transfer coefficients tend to be reported within the laminar flow regime compared to the forecasts of standard correlations intended for straight and also smooth tubes. The Experimental results show how the outer tube side heat transfer coefficients are usually smaller compared to inner side heat transfer coefficients with a factor of almost 1.5 and also 3.4 in counter flow as well as parallel flow deal, respectively. The agreement with predictions is very good for that counter flow arrangement, but not very good for this parallel flow arrangement.

Sunil S. Shinde et al. [5] offers studied concerning the performance Progress in Single phase Tubular Heat Exchanger utilizing continuous Helical Baffles as well as investigated that how the performance connected with tubular heat exchanger could be improved by helical baffles rather than conventional segmental baffles. The application of helical baffles in heat exchanger minimizes shell side pressure drop, pumping price, size, weight, fouling etc. as evaluate to segmental baffle intended for new installations. The helix changer type heat exchangers may save capital cost along with operating and also maintenance cost and so improves this reliability and availability of process plant in an inexpensive way. For that helical baffle heat exchangers, the ratios of heat transfer coefficient to help pressure drop are higher than those of a conventional segmental heat exchanger. Because of this the heat exchangers using helical baffles can have a greater heat transfer coefficient while consuming identical pumping power. It could be concluded that proper baffle inclination angle provides an optimum performance of heat exchangers.

Apu Roy, D.H.Das [6] the existing work have been carried out using a view to predicting this performance of a shell and also finned tube heat exchanger in the light connected with waste heat recovery application. Energy obtainable in the exit streams of much energy the conversion devices such as I.C engine gas turbine and so on goes because waste, if not utilized correctly. The performances of the heat exchanger have been evaluated by utilizing the CFD package fluent 6.3.16 and the available values are compared with experimental values. By thinking about different heat transfer fluids the performance in the above heat exchanger may also be predict. The effectiveness parameters of heat exchanger such as effectiveness, overall heat transfer coefficient, energy extraction rate etc, are already taken in this particular work.

IV. RESULT & DISCUSSION

The analysis of the 3D Model have been performed by Using FLUENT ANSYS the actual Analysis performed by using with different orientation of segmental baffles & without having baffles. For evaluation the input data is static for both types. During these Projects work various design consideration of choice of tube material, development of analytical model and analytical thing to consider assumptions, procedure and input parameters. The developments of heat exchanger concentrate for lower

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pressure drop and higher heat transfer coefficient. The outcomes obtain for with segmental and without baffles in FLUENT ANSYS. The FLUENT ANSYS Results have been obtained for different orientation of segmental baffles & without having baffles:-

- Dimension of a STHX:-

Parameter	Dimension
Shell Diameter(mm)	207
Tube outside Diameter(mm)	19
Tube Pitch	50
Length of Tube (mm)	1500
Number of Tubes	7
Tube to Tube Clearance	31
Shell Length	1500
No of Baffles	5
No of Passes	1

- Properties of Fluid:-

Parameter	Symbol	Unit	Cold Water (Shell)	Hot Water (Tube)
Fluid			Water	Water
Specific Heat	C_P	KJ/Kg.K	4.178	4.178
Thermal Cond	K	W/m.K	0.615	0.615
Viscosity	μ	Kg/m.s	0.0013	0.0013
Prandtl 's No.	Pr		5.42	5.42
Density	ρ	Kg/m3	998.2	998.2

- MATERIAL PROPERTIES:-

- MATERIAL PROPERTIES OF STEEL:-

Property	Value
Density (×1000 kg/m^3)	7.871
Poisson's Ratio	0.27-0.30
Thermal Conductivity(W/m-K)	59.5
Specific Heat (J/kg-K)	481

- MATERIAL PROPERTIES OF COPPER:-

Property	Value
Density (×1000 kg/m^3)	8.960
Poisson's Ratio	0.34
Thermal Conductivity(W/m-K)	401
Specific Heat (J/kg-K)	385

- MATERIAL PROPERTIES OF BRASS:-

Property	Value
Density (×1000 kg/m^3)	8.600
Poisson's Ratio	0.331
Thermal Conductivity(W/m-K)	115
Specific Heat (J/kg-K)	375

- Boundary conditions:-

1) Temperature's:-

Side	ºC
Hot Fluid inlet Temp. (T1)	63
Cold Fluid Inlet Temp. (t1)	33

2) Velocity:-

Tube Side Velocity	Shell Side Velocity
1 m/sec	1 m/sec
2 m/sec	1 m/
3 m/sec	1 m/

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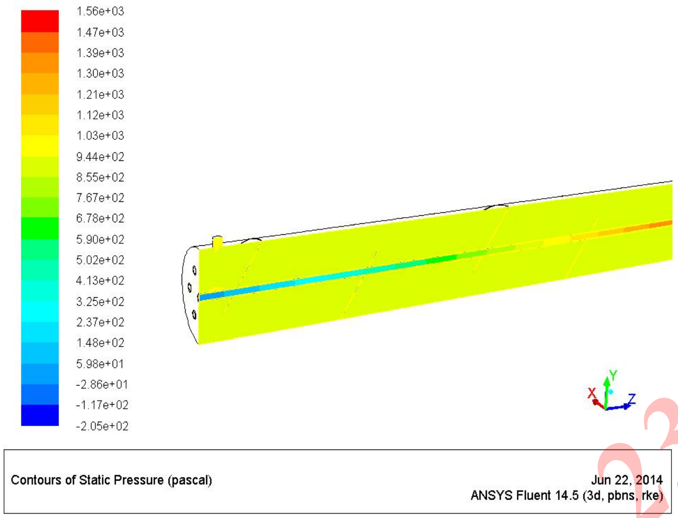
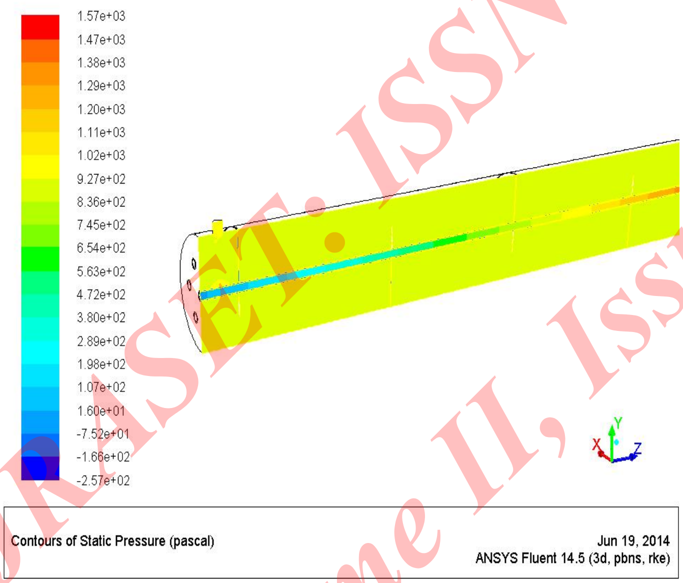
Fig.1.1 Pressure of STHX with tube material using Brass with 30^0 & 0^0 Baffles at different velocity in (m/sec).

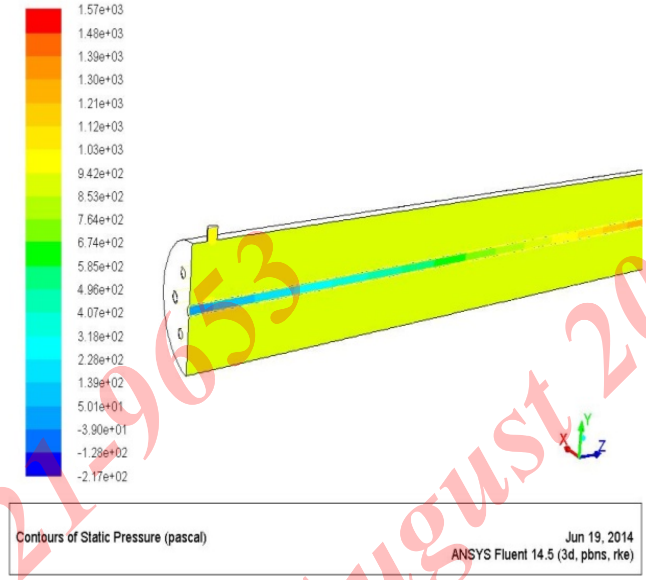


Static Pressure at 30º baffles V=1 (m/s).



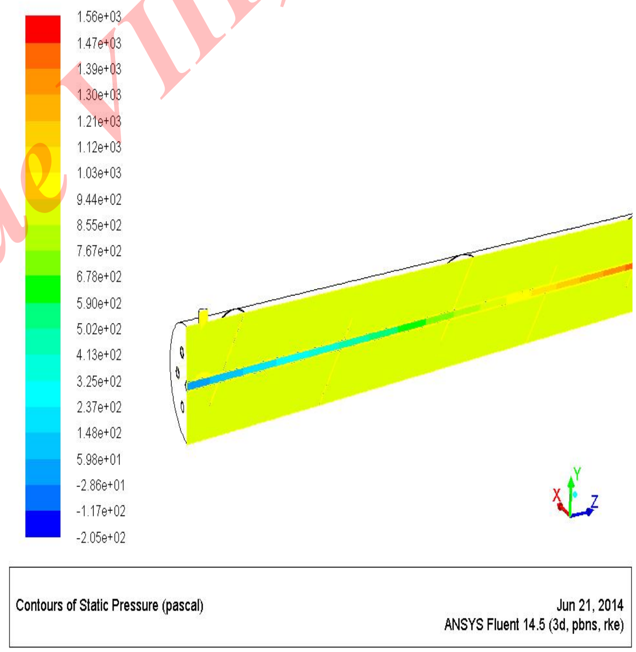
Static Pressure at 0º baffles V=1 (m/s)

Fig.1.2 Pressure of STHX with tube material using Brass at without Baffles & different velocity in (m/s)

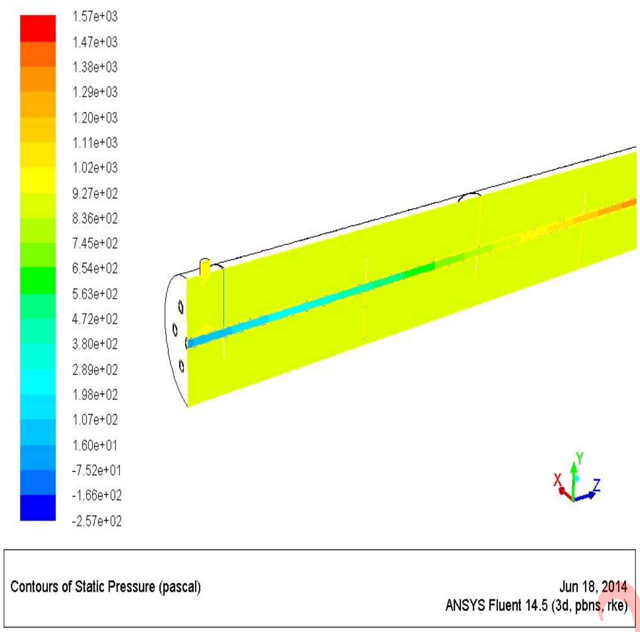


Static Pressure at without baffles V=1 (m/s).

Fig.1.3 Pressure of STHX with tube material using Copper with 30º& 0º Baffles at different velocity in (m/s).

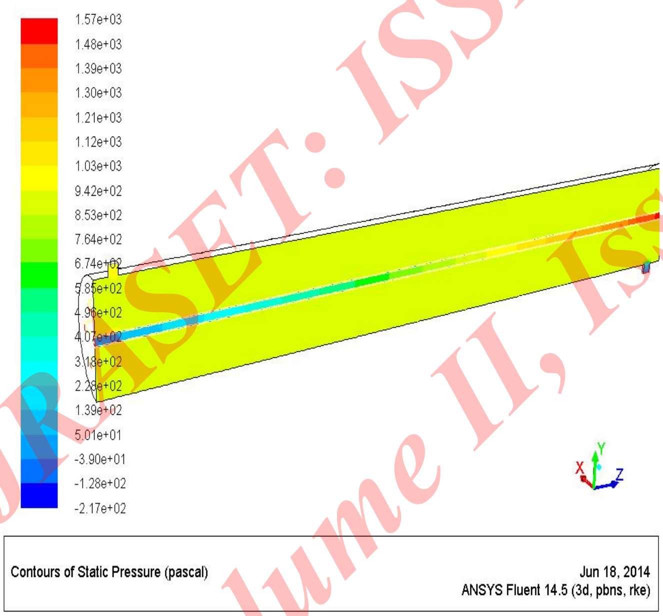


Static Pressure at 30º baffles V=1 (m/s).



Static Pressure at 0° baffles V=1 (m/s).

Fig.1.4 Pressure of STHX with tube material using Copper at without Baffles & different velocity in (m/s).



Static Pressure at without baffles V=1 (m/s).

Comparisons of Result

Table 1.2 For the Outlet Temperature of the Shell Side and Tube Side.

Baffle Inclination Angle in (Degree)	Outlet Temperature Of Shell side in (k).	Outlet Temperature Of Tube side in (k).
Without Baffles	320	330
0°	317	327
30°	314	324

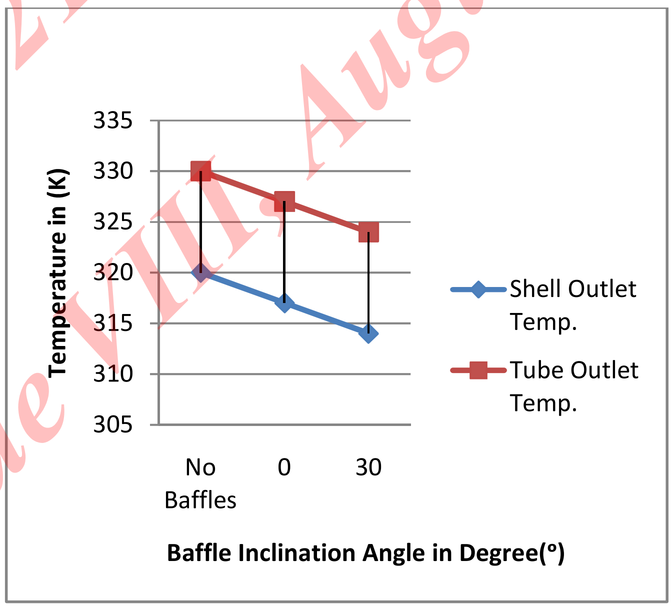


Fig.1.5 Plot of Baffle inclination angle vs. Outlet Temperature of Shell and Tube Side.

- It has been found that there is much effect of outlet temperature of shell side & tube side with increasing the baffle inclination angle from 0° to 30° & without having baffles.

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Table 1.3 For the Pressure Drop Inside Shell.

Baffle Inclination Angle in (Degree)	Pressure Drop Inside Shell (Pa)
Without Baffles	997.3923
0°	998.1241
30°	972.627

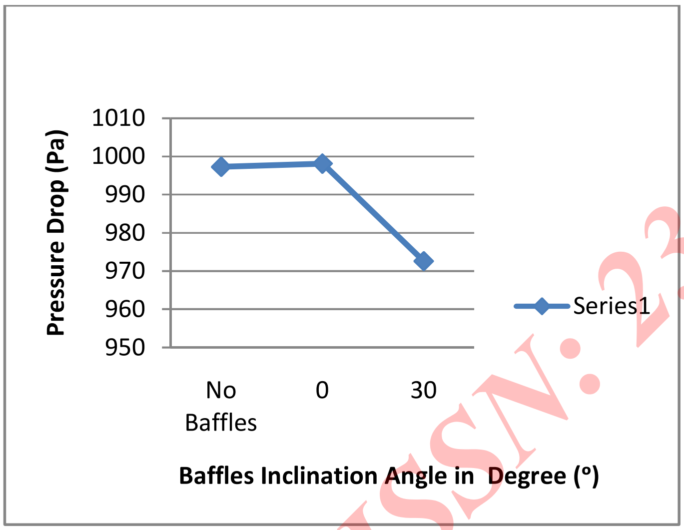

Fig.1.6 Plot of Baffle angle vs. Pressure Drop.

➢ The shell-side pressure drop is decreased with increase in baffle inclination angle i.e., as the inclination angle is increased from 0° to 30°. The pressure drop is decreased by 0.1 %, for heat exchanger without having baffle and by 2.6 % for heat exchanger with 30° baffles inclination compared to 0° baffle inclination shell & tube heat exchanger as shown in fig. 1.6. Hence it can be observed with increasing baffle inclination pressure drop decreases, so that it affect in heat transfer rate which is increased.

Table 1.4 For Heat Transfer Rate across Tube side.

Baffle Inclination Angle in (Degree)	Heat Transfer Rate Across Tube side (KW)
Without Baffles	4.41
0°	6.39
30°	8.52

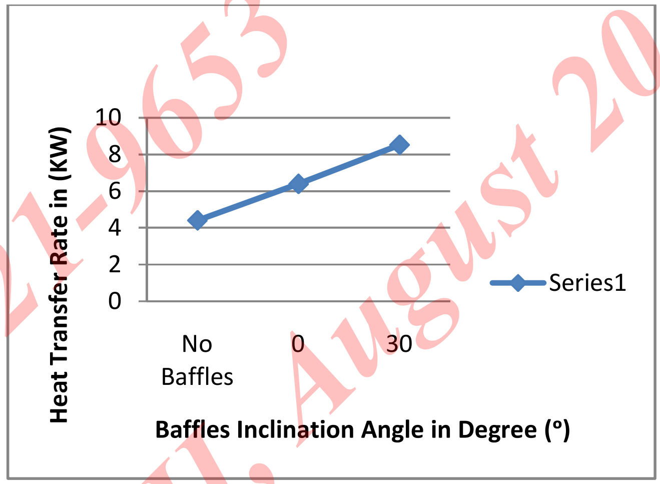

Fig.1.7 Heat Transfer Rate vs. Baffle inclination angle.

1. The shell side of a small shell-and-tube heat exchanger is modeled with sufficient detail to resolve the flow and temperature fields.
2. The pressure drop decreases with increase in baffle inclination.
3. The heat transfer rate is increase when the baffle inclination is increase.

V. CONCLUSION

In this project, CFD evaluation of single pass heat exchanger was done to evaluate the performance of the shell & tube type heat exchanger with and without having baffles situated at Outer pipe. The setup provides the following conclusions:

- Study of heat transfer in the heat exchanger at different velocity.

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- The end result coming out from heat exchanger having baffles located at outer pipe will be more efficient via heat exchanger without having baffles.
- The outcomes of heat transfer coefficient coming out by utilization of 30º baffles will be more efficient than 0º baffles. As the angle of inclination increases, the heat transfer rate of heat exchanger also increases.
- As the Reynolds number increases in the heat exchanger, the heat transfer coefficient will increase.

VI. SCOPE OF FUTURE WORK

While using the CFD evaluation of Single Pass Shell & Tube Heat Exchanger with Different Orientation of Baffles and Without Baffles with counter flow of fluid, test runs is going to be made for at least three different velocities (Reynolds Numbers). The three different baffle orientations (i.e. 0º & 30º) will be studied for that corresponding velocity, inlet temperatures, and counter flows resulting in total 150 test runs. The analysis of heat transfer rate in heat exchanger can be concluded by means of same baffle spacing. The experimental results are compared with the CFD final results and correlations will be developed with respect to these conditions for that Nusselt number and other flow parameters.

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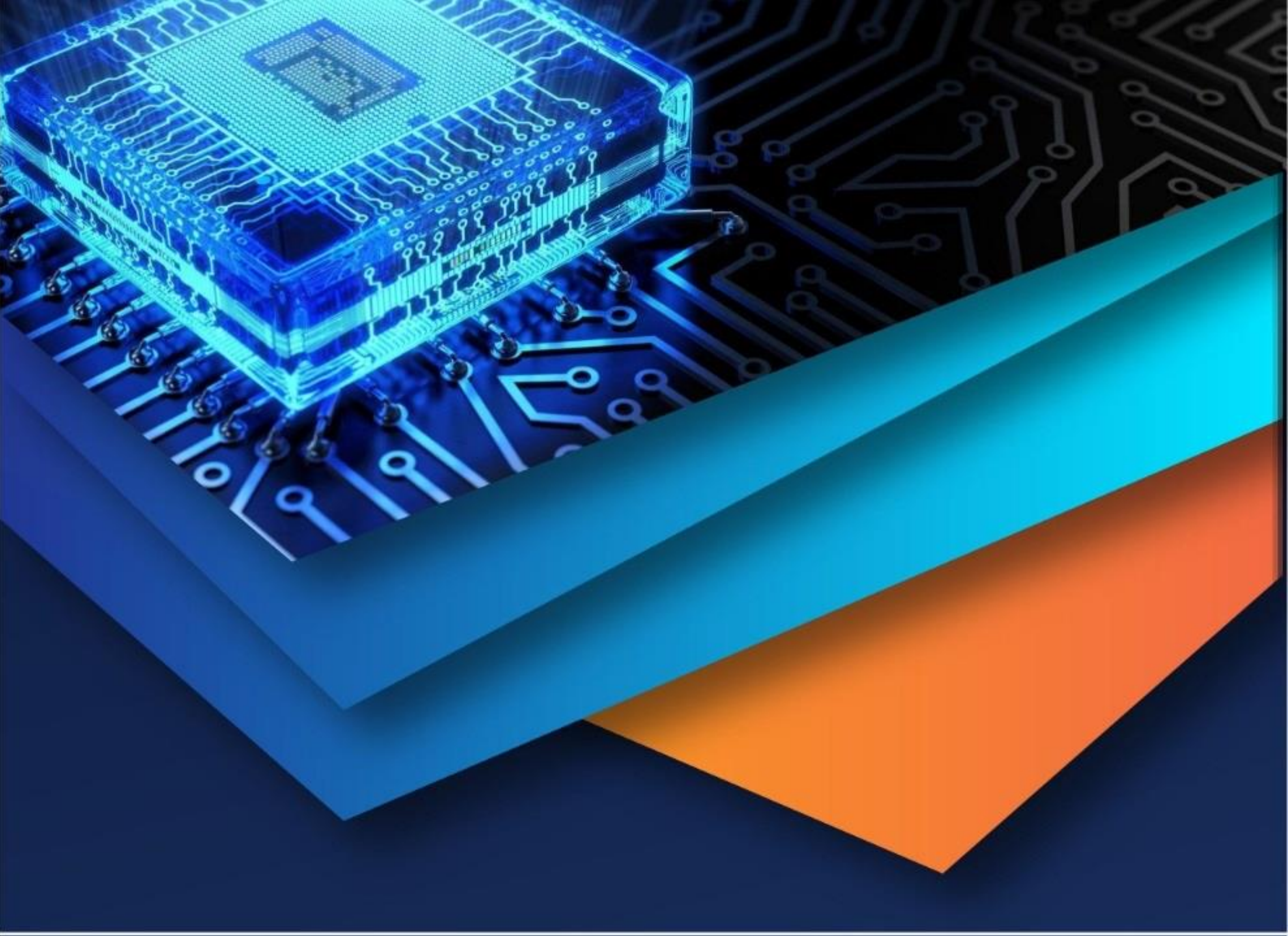

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