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Computational Fluid Dynamics Analysis of Shell and Tube Heat Exchanger with Different Baffles

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ABSTRACT: A numerical study has been performed on a unidirectional shell and tube heat exchanger with segmented baffles. The heat transfer process and flow pattern are studied numerically by varying the number of baffles. The standard k-e model is used to solve the above problem. A numerical simulation was performed for three different cases of baffle spacing with a square tube bundle. Numerical solutions were obtained by solving 3D equations for continuity, momentum, energy and perturbation (k-e) using a commercial CFD solver. For the analysis of the phenomenon, the number of baffles was taken as the change parameter; other parameters such as speed, temperature, pressure and deflector shear are kept constant. The results obtained from the digital solution were further analyzed to obtain the effect of the number of baffles on the heat transfer rate and the shell side pressure drop.

Key Word:shell and tube heat exchanger, segmental baffle, k-e model

I. INTRODUCTION

In the era of growing population of world, per capita income along with demand for fresh and processed food and drinks is increasing enormously resulting in critical need in effective process technologies to produce them. Right nowadays, half of the world‘s inhabitant‘s lives in a town or city and this can be expected to be 9 billion people on the planet by 2050. Processed nutrients and liquid refreshment from name-brand manufacturers, packed to suit the needs of customers, are in just as high request as fresh products – particularly among urban buyers. Heat exchange is a key element that points on these products‘ journey to the person who lastly consumes. Cooling is vital but not sufficient alone; in addition, loss of liquid and vitamins must be efficiently prevented. Heat exchangers form us set criteria with awe to energy efficiency, mid-air throw and effectiveness. These are crucial features for accessibilities, food distribution centers, storerooms, invention halls and hypermarkets require tremendous cooling duty. The heat exchangers can be upgraded to execute heat-transfer duty by transferring of heat and upsurge techniques as active and passive techniques. The active technique involves exterior forces, e.g. electric field and surface vibrations etc. The passive technique requires fluid flow behavior and distinct apparent geometries. Curved tubes are used for transferring of heat improvement procedures, relatively a lot of heat transfer applications.

Shell & Tube coil heat exchanger is the modern improvement of heat exchangers, to fulfill the industrial demand.

Pressure drop features are essential for calculating fluid effect to overwhelmed pressure drops and for arrangement of necessary mass flow rates. The pressure drops are also a function of the pipe curvature. The curvature creates secondary flow arrangement which is perpendicular to main axial stream path. This secondary flow has insignificant capability to increase heat transfer allocated to mixing of the fluid. The strength of secondary flow established in the tube. It is the value of tube diameter and coil diameter. The force which arises due to curvature of the tube and results in secondary flow advancement with increased rate of heat transfer is centrifugal force.

Shell and Tube Heat Exchanger

For high pressure application, there is a heat exchanger called shell and tube heat exchanger is used. It is an indirect contact type heat exchanger under the subdivision of recuperator. It is a most versatile heat exchanger. By some modification, it can be act as a parallel flow, counter flow and cross flow as well. Shell and tube heat exchanger consists of a shell, tubes and headers. Tubes are generally made of cylindrical shape with circular cross section whereas shell has a wide variety according to the requirement. One fluid flows through the tubes and the other fluid pass through the shell. Heat exchanges between these two fluids are by convection-conduction- convection mode. Shell and tube heat exchanger has high value of log mean temperature difference correction factor.

A simple shell and tube heat exchanger can work as a parallel flow and counter flow heat exchanger but to make it a cross flow heat exchanger, some modification is to be done. Introducing baffles in the shell side is one of the modification.

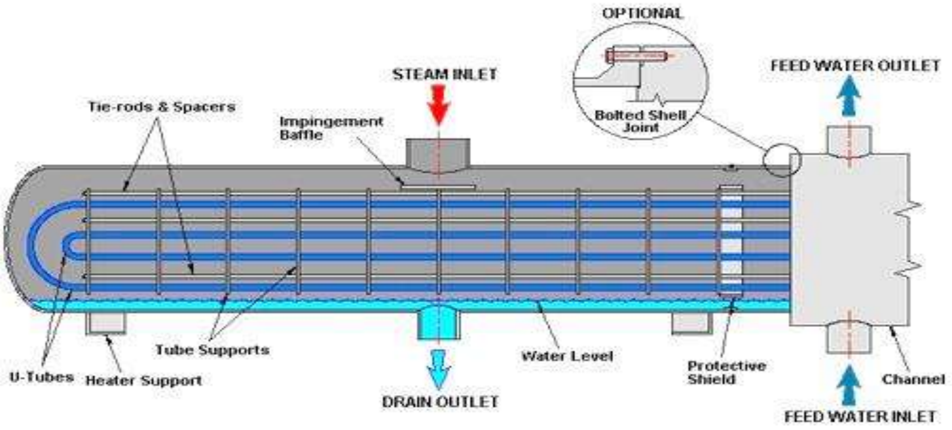


Figure 1 :Shell & Tube Heat Exchanger

II. LITERATURE REVIEW

Gyan Prakash et.al.[1]Shell and coiled coils ar eminent involute tubes which can be employed in variety of solicitations e.g. warmness recuperation, air-conditioning and maintenance schemes, chemical reactors and dairy farm practices. For this, his planned work on CFD to scrutinize the coiled coil by means of victimization ANSYS 15. A 3D fashion of CAD version of coiled coil of tube outer diameter (do) 16 millimetre, inner diameter of coiled coil (di) twelve millimetre, pitch of 26.3mm, pitch coil DIA. 86 mm, tube period of 235 millimetre, shell diameter is 110 millimetre and shell length is 215 millimetre, is generated with the aid of victimization ANSYS fluent fifteen.analytical investigations ar done on the shell and whorled coil device, to see pressure drop and temperature distribution of a water as a base fluid and Fe_2O_3 as a nanofluid on shell and whorled coil flowing underneath streamline flow conditions. By perceptive the CFD analysis results, the pressure drop is additional in hot fluid of Fe_2O_3 nanofluid with water as a base fluid in shell and whorled coil device.

Pranita Bichkar et.al. [2] doing research on the impact of various types on Shell and Tube Heat Exchangers This research offers numerical simulations of unmarried segmental, double segmental, and vertical arrangements. This implies that the shell has an influence on the pressure drop of the shell and tube warmth exchanger. Unmarried-segmented blocks exhibit the creation of dead zones in which the warmth switch cannot be turned green. When compared to single segment beams, double section beams lessen vibration damage. Because dead zones are eliminated when using a vertical shell, pressure is reduced. Fewer dead zones result in a greater heat switch. Reduced stress results in less pump energy, which boosts system efficiency. The comparison results reveal that the vertical is more beneficial than the horizontal.

Vidula Vishnu Suryawanshi et.al. [3] carried out research on the designing and assessment of helical coil heat exchangers CFD analyses are performed in this work on several compounds with varying sizes. The following tasks must be completed to further develop the helical heat exchanger: wall temperature and consistent wall warmness flux in both laminar and turbulent drift. To maximise the heat transfer coefficient, examine the results and alter the spiral winding pitch.

Vishal Momale et.al. [4]] Examine the performance of a conical helical tube warmness exchanger with direct and conical shell cfd usage. Computational fluid dynamics was used to complete the study of a conical helical tube heat exchanger. Heat transmission may evolve significantly when the larger shell fluid comes into contact with the tube fluid when we employ a conical shell rather than a helical shell. With a conical shell configuration, the strain decrease will boom. If we utilise baffles, we can still boost the warmth switch.

The Mohamed Ali et.al. [4] The experimental inquiry of herbal convection created to examine, constant type natural Convection became obtained from turbulent herbal convection to water. The experiments were carried out with a coil diameter to tube diameter ratio of four for five and ten coil tubes, as well as a pitch outer diameter ratio of five. He correlated Rayleigh amount for two distinct coil sets and discovered that the warmth switch coefficient falls with coil length for tube diameter do =.012m but increases with coil length for do=.008m. For a most heat switch coefficient, a tube diameter of zero.012 m with either five or ten coil turns yields a significant D/d0.

R. Patil et.al. [5] A design method for a spiral coil heat exchanger was suggested. The heat transfer coefficient is calculated primarily based on the internal diameter hello of the coil using the Sieder-Tate relationship or the instantly pipe method by plotting the Colburn coefficient JH against Re. External heat transfer coefficients are calculated using correlation for specific stages of Reynolds numbers. Spiral coil warmness exchangers are preferred when space is limited, as well as in low drift or slow flow circumstances.

N. Ghorbani et.al. [6] For the purposes of this paper, an experimental examination of the thermal performance of shell and coil warmth exchangers was carried out. The calculations were done in steady state, and the trials were done in laminar and turbulent glide within the coil. It has been established that the tube aspect to shell mass drift ratio is effective for the heat exchanger's axial temperature profile. He observed that raising the mass flow ratio reduces the logarithmic average temperature difference and decreasing the mass waft rate reduces the adjusted effective temperature distinction.

Sunil Kumar et.al. [7] The first configuration of a helical coil warmth exchanger with fins was explored, as well as stress and temperature comparisons with a standard structure. The end outcome of this investigation is an increase in the overall heat switch coefficient within the domain. Increase the strain decrease within the range. The bloodless water outlet temperature is increased to 320k while the water outlet temperature is dropped to 315k. The total stress decrease increases as the temperature rises. When the CFD numbers were compared to the prior statistics, the entire pressure drop for Case 2 increased to 0.65 bar. The system's overall performance ranges between 5% and 6%.

K. Abdul hamid et.al [8] Pressure decrease in ethylene glycol (EG)-based nanofluids was investigated. Nanofluids are created by diluting TiO2 in a 60:40 volume ratio of mixed water and EG base fluid in three quantity concentrations of 0.5%, 1.0%, and 1.5%. Experiments were carried out in a waft loop with a horizontal tube examination phase at various drift rate values in a variety of Reynolds numbers beneath 30,000. The experimental pressure drop of TiO2 nanofluid results were compared to the Blasius equation for the base fluid. An increase in pressure drop was detected with increasing nanofluid volume attention, and a slight decrease in strain drop was discovered with increasing nanofluid temperature. He discovered that TiO2 did not increase significantly compared to EG liquids. The working temperature of nanofluids reduces the pressure drop due to the reduction of nanofluid viscosity.

Paranisamy et al [9] Warmth switch and strain decrease in a conical spiral tube heat exchanger using MWCNT/water multi-walled carbon nanotubes were determined. Surfactant calculations were performed on MWCNT/water nanofluids with atomic extent absorption of 0.1%, 0.3%, and 0.5% utilising a two-step technique. The study of turbulent drift became revealed inside the range of Din vast variation 2200 De 4200. The volume concentration of nanofluid with assumed Nusselt numbers of 0.1%, 0.3%, and 0.5% became 28%, 52%, and 68% more than water, respectively. The pressure drop of 0.1%, 0.3%, and 0.5% nanofluids is 16%, 30%, and 42% more than that of water, respectively.

Hemasunder Banka et al. [10] carried out a scientific evaluation on shell and tube heat exchangers with pressurised convection heat switch to identify the bodily appearance of nanofluid flows with varying extent fraction and mixing with water. Titanium carbide (TiC) and titanium nitride are two nanofluids (TiC). TiN) and ZnOnanofluids with extremely high concentrations (0.02, 0.04, 0.07, and 0.15%) drift in turbulent circumstances. CFD study of heat exchangers is carried out by using nanofluid houses with certain volume fractions to provide temperature distributions, heat switch coefficients, and heat switch coefficients. He discovered that heat switch coefficients and heat switch coefficients increase as quantity fractions increase.

III. COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics, as the name implies it is a subject that deals with computational approach to fluid dynamics with numerical solution of the equations which bring about the flow of the fluid and although it is also called computational fluid dynamics; it does not just deal with the equations of the fluid flow, it is also generic enough to be able to solve simultaneously together the equations that direct the energy transfer and as well the equations that determine the chemical reaction rates and how the chemical reaction proceeds and mass transfer takes place; all these things can be tackled together in an identical format. So, this outline enables us to deal with a very complex flow circumstances in reasonably fast time, such that for a particular set of conditions, an engineer will be capable to simulate and see how the flow is taking place and what kind of temperature distribution there is and what kind of products are made and where they are formed, so that we can make changes to the parameters that are under his control to modify the way that these things are happening. So, in that case CFD becomes a great tool of design for an engineer. It is also a great tool for an analysis for an examination of a reactor or equipment which is not functioning well because in typical industrial applications.

IV METHODOLOGY

CFD Programs

All established CFD software contain three elements

(i) A pre-processor
(ii) The main solver
(iii) A post-processor

The preprocessor

Pre-processing is the first step of CFD analysis in which the user

(a) Characterizes the displaying targets,
(b) Distinguishes the computational area, and
(c) Outlines and makes the framework

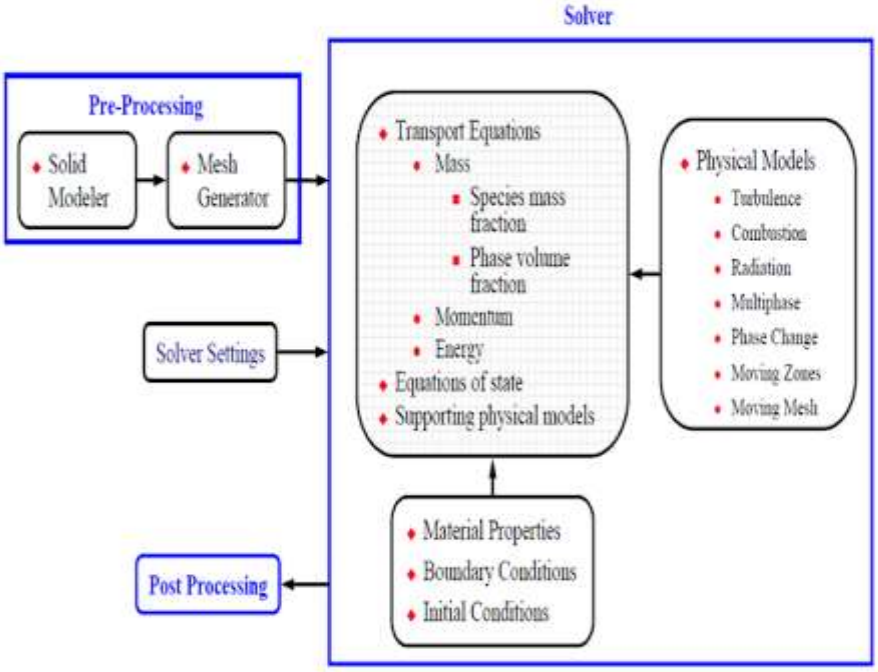


Figure 2: Overview of CFD

The main solver

The main solver does following functions: Selection of physical model.

(d) Definition of material properties
(e) Define boundary conditions
(f) Solution initialization
(g) Setting of relaxation factor
(h) Setting of convergence criteria
(i) Run calculation
(f) Saving results

The post processor

The post-processor is the last some portion of CFD programming. It helps the client to investigate the outcomes and get valuable information. The outcomes might be shown as vector plots of vector amounts like speed, form plots of scalar variables, for instance weight and temperature, streamlines and liveliness if there should arise an occurrence of insecure reproduction. Worldwide parameters like skin grinding coefficient, lift coefficient, Nusselt number and Colburn variable and so on might be registered through suitable recipes. This information from a CFD post-processor can likewise be sent out to perception programming for better show and to programming for better diagram plotting.

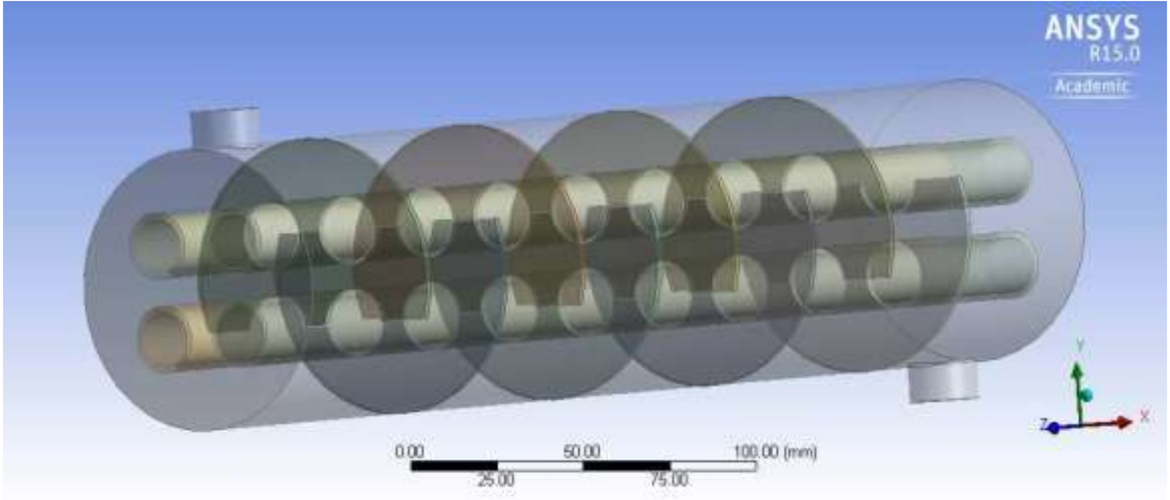


Fig.3 Overallgeometryofshellandtubeheatexchangerwith8baffles

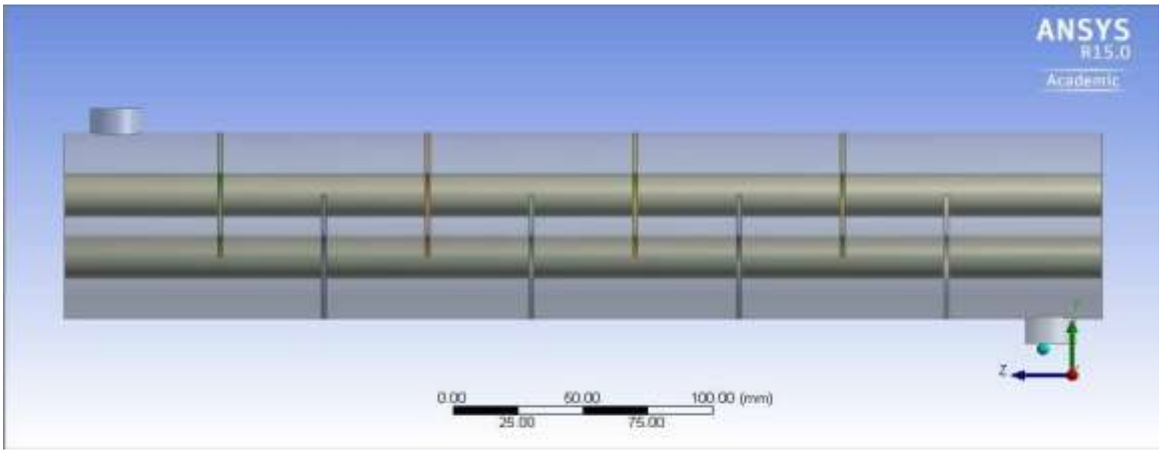


Fig 4 Front view of geometry with 8 baffles

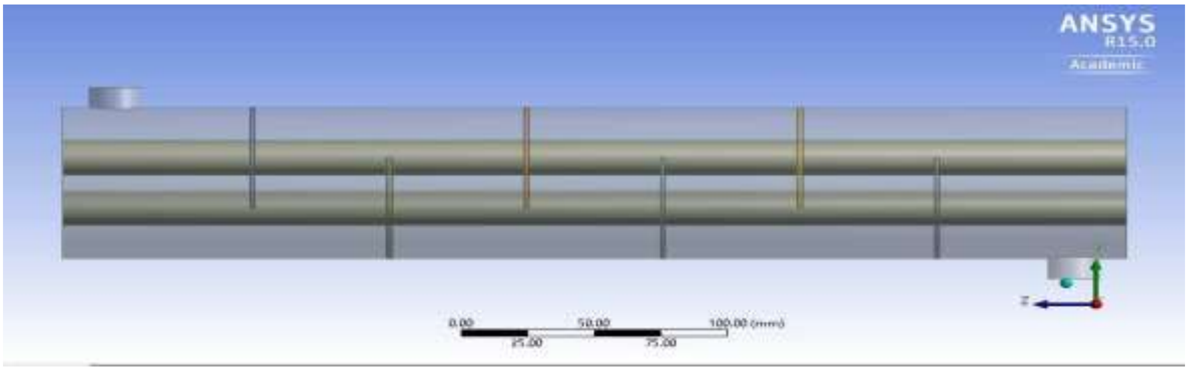


Fig 5 Front view of geometry with 6 baffles

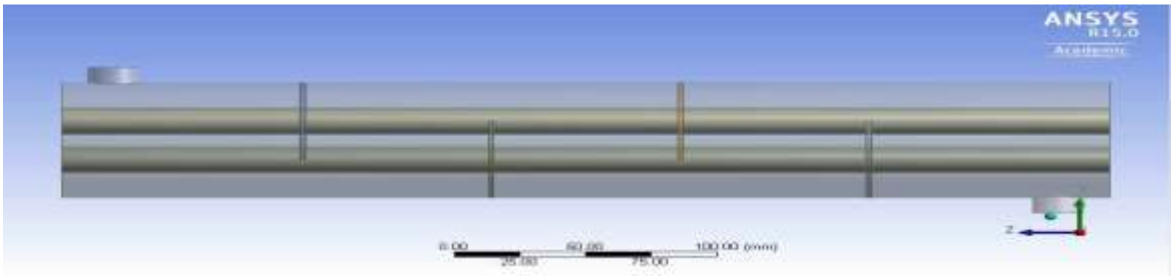


Fig 6 Frontviewofgeometrywith4baffles

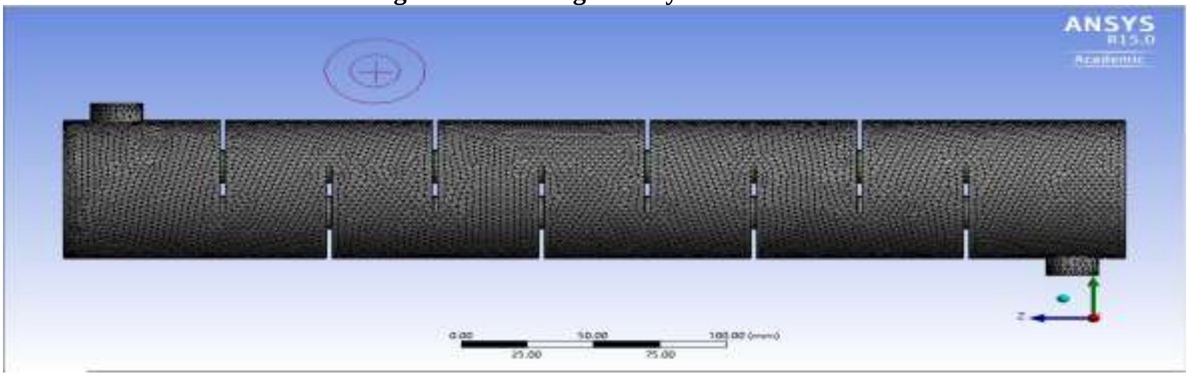


Fig 7Overallmeshing

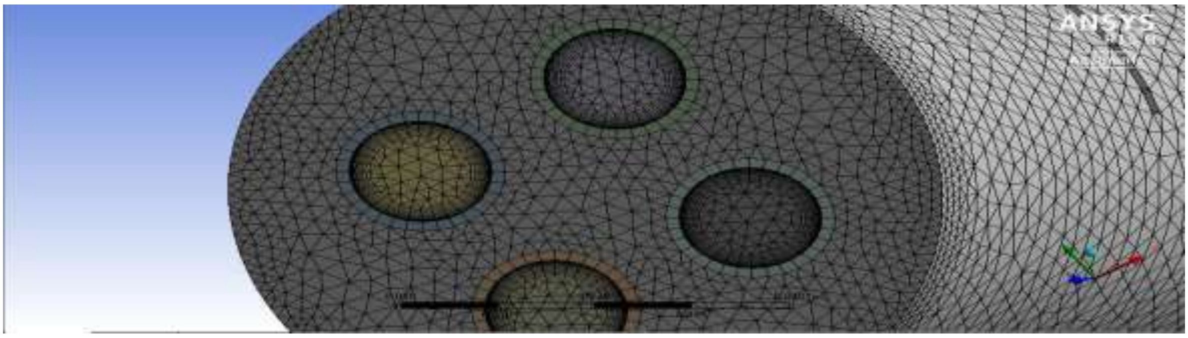


Fig 8 Magnifiedviewofmeshing

Solver	**Model**	**Material**
PressureBased,steadystate	Standardk-□	Fluid-water,solid-copper

Table1:DetailsofSolver,ModelandMaterials

Density	998.2 kg/m^3
SpecificHeat	4182J/kg-K
Thermalconductivity	0.6W/m-K
Viscosity	0.001003kg/m-s

Table2:Propertiesofwater

Density	8978 kg/m^3
SpecificHeat	381J/kg-K
Thermalconductivity	387.6W/m-K

Table3:Propertiesofcopper

Pressure-velocitycoupling	SIMPLEscheme
Gradient	Green-GaussNodeBased
Pressure	Secondorder
Momentum	Secondorderupwind
Turbulentkineticenergy	Firstorderupwind
Turbulentdissipationrate	Firstorderupwind
Energy	Secondorderupwind

Table4:Solutionmethods

V RESULTS & DISCUSSION

Velocity contour

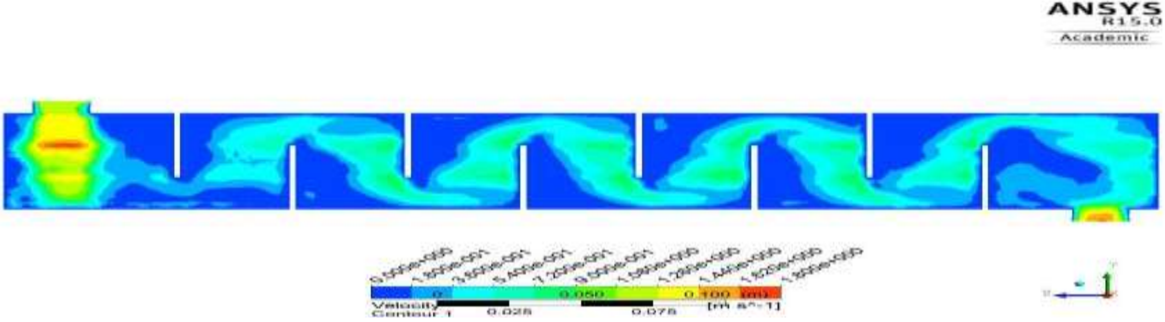
Velocity contour, streamline and velocity vector plots showing that when hot fluid enters the shell and passing through the baffles, there is a formation of recirculation zone in the back face of the baffles. In that region, flow is less as shown in figures 9, 10 and 11 respectively.

Temperature contour

Temperature contour as shown in figure 12 shows how temperature varying in different zones. From velocity contour it is known that in back face of baffles flow is very less so the temperature in the back face of the baffles are also less as compare to their front face.

Pressure Contour

Figure 13 shows that pressure is gradually decreasing as fluid flows through the shell as well as pipe. This pressure drop is the deciding parameter for the pumping requirement. If pressure drop is more then more pumping power is required.



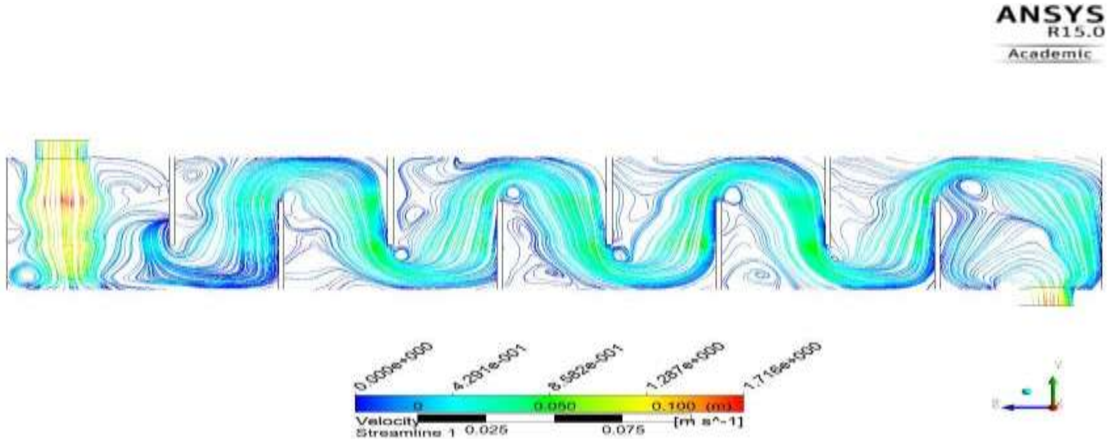


Fig 9 Velocity contour

Fig 10 streamlines

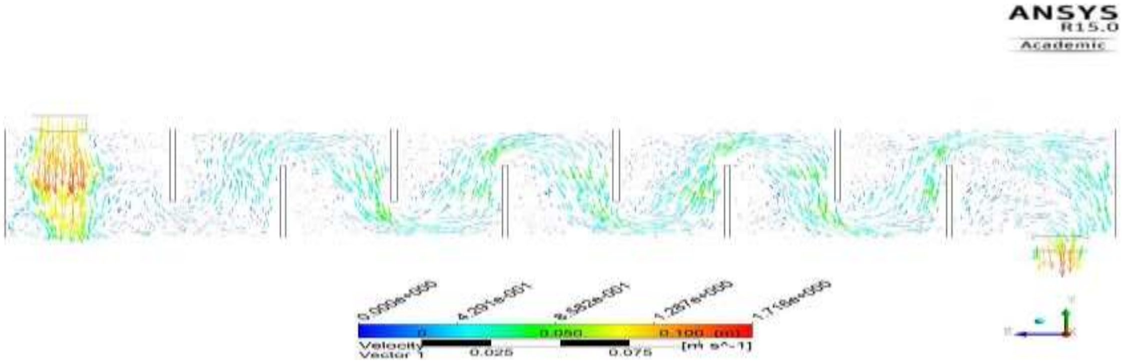


Fig 11 Velocity vector

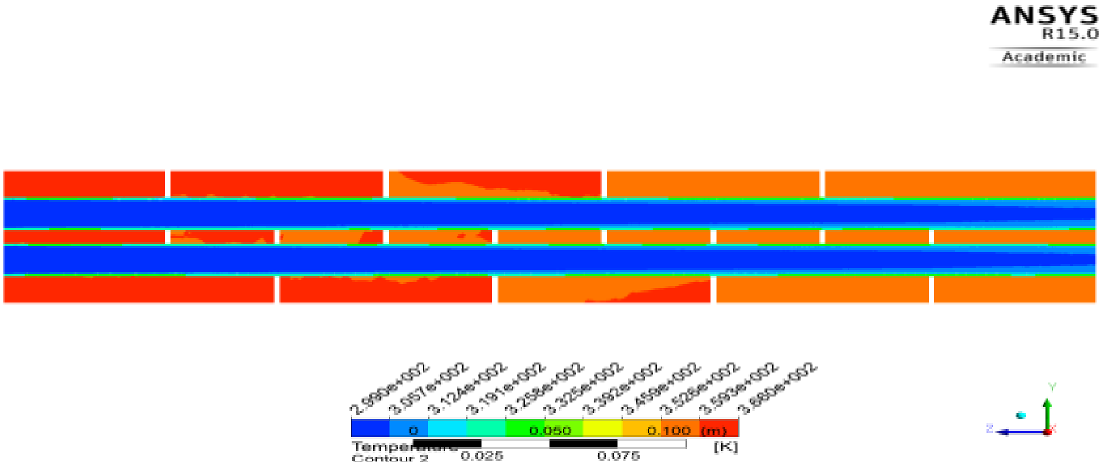


Figure 12: Temperature contour

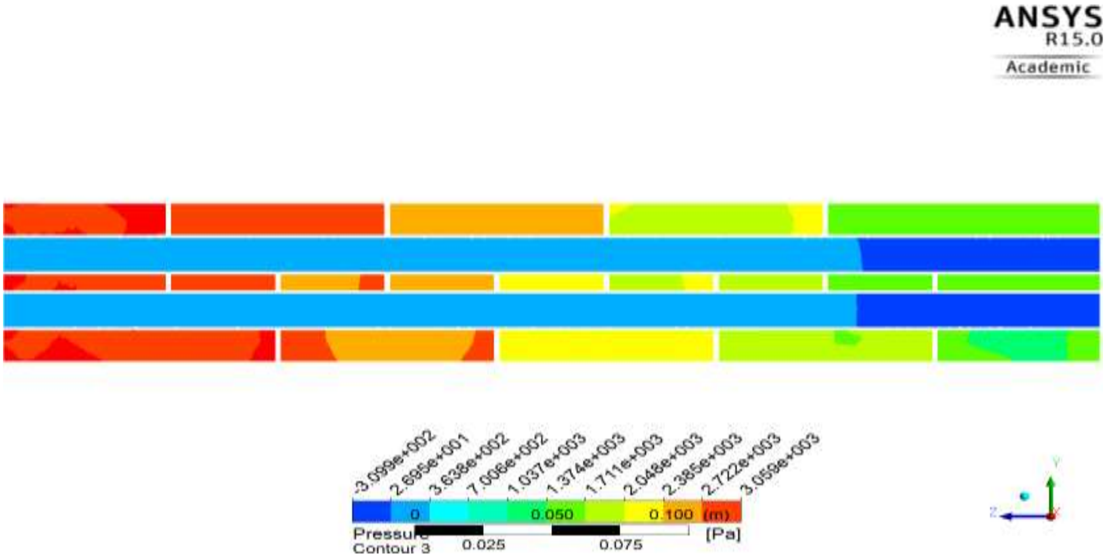


Figure 13: Pressure Contour

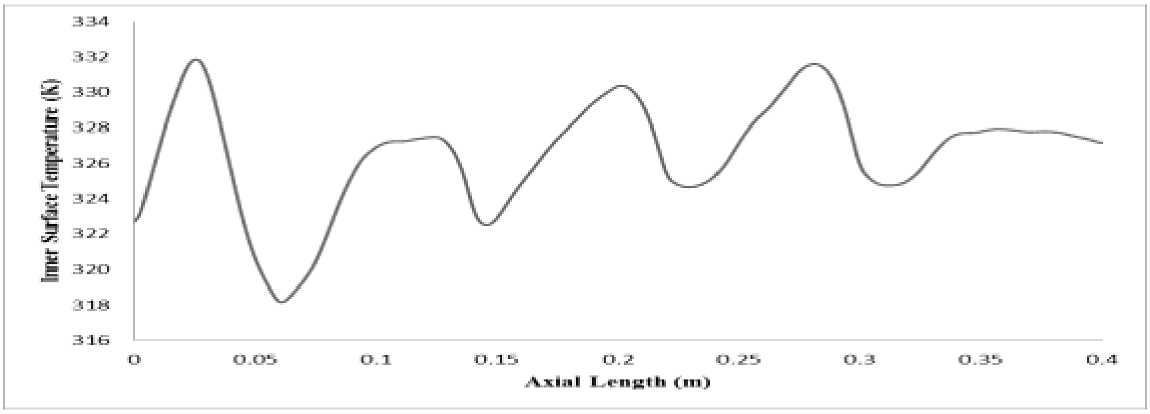


Figure 14: Inner surface temperature v length

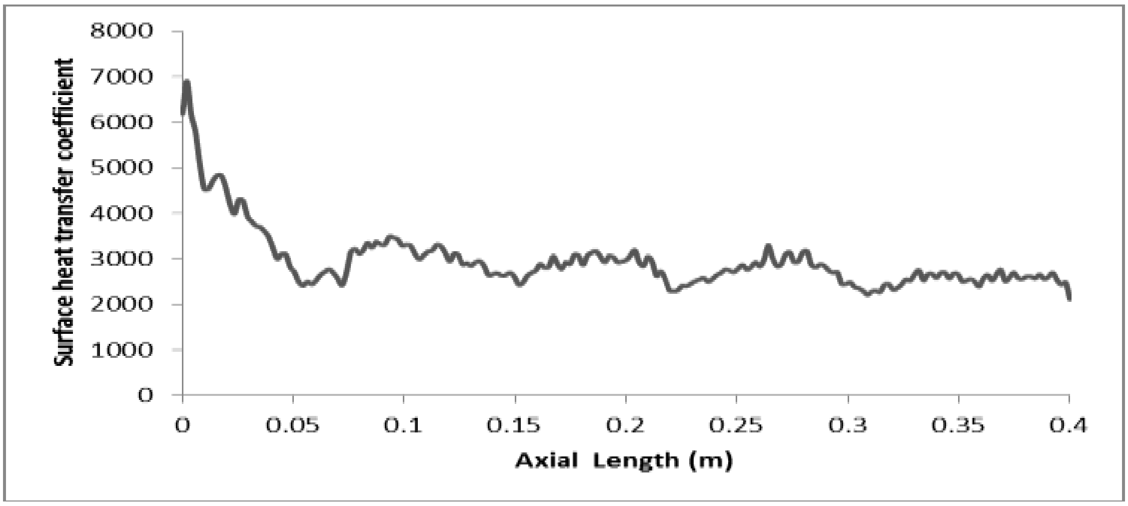


Figure 15: Surface heat transfer coefficient vs length

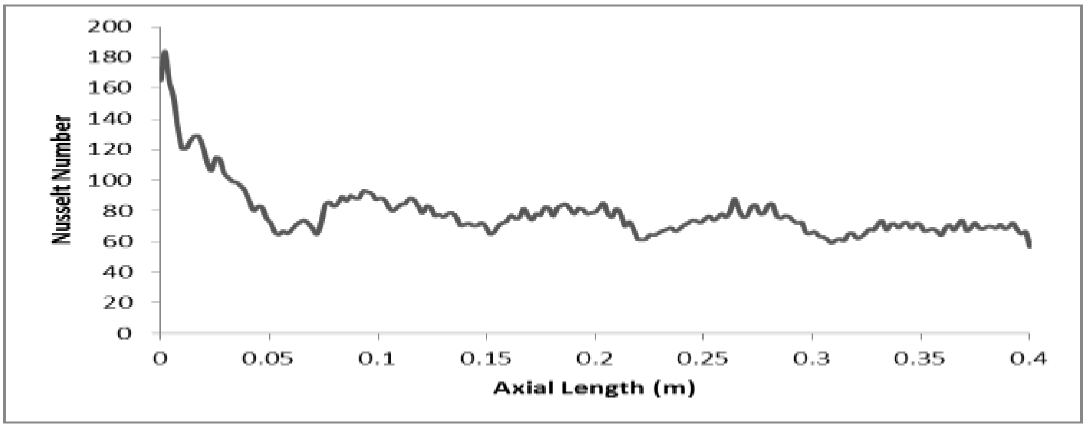


Figure 16: Nusselt number vs length

Number of baffles	Heat transfer rate (W)
4	8043.8305154292
6	9884.910562944
8	11053.37143

Table 5: Heat transfer rate in various cases

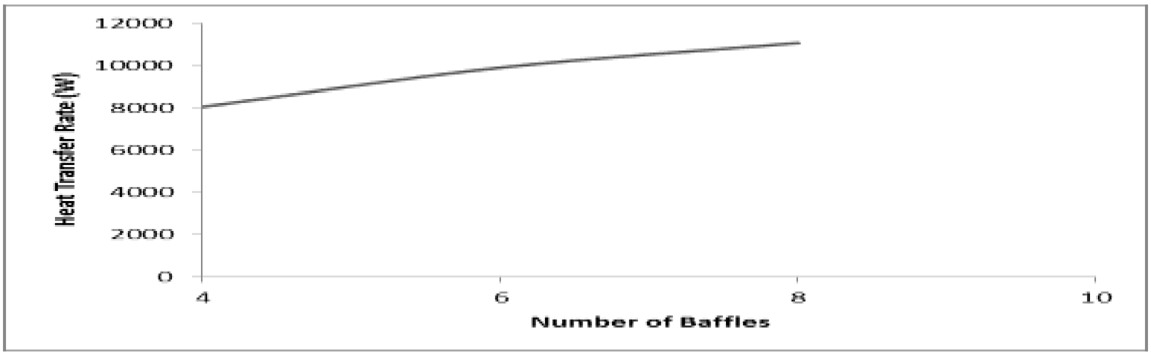


Figure 17: Heat transfer rate vs number of baffles

Table 6: Shell side pressure drop in various cases

Number of baffles	Shell side pressure drop (Pa)
4	2116.44502
6	2695.90933
8	3160.72314

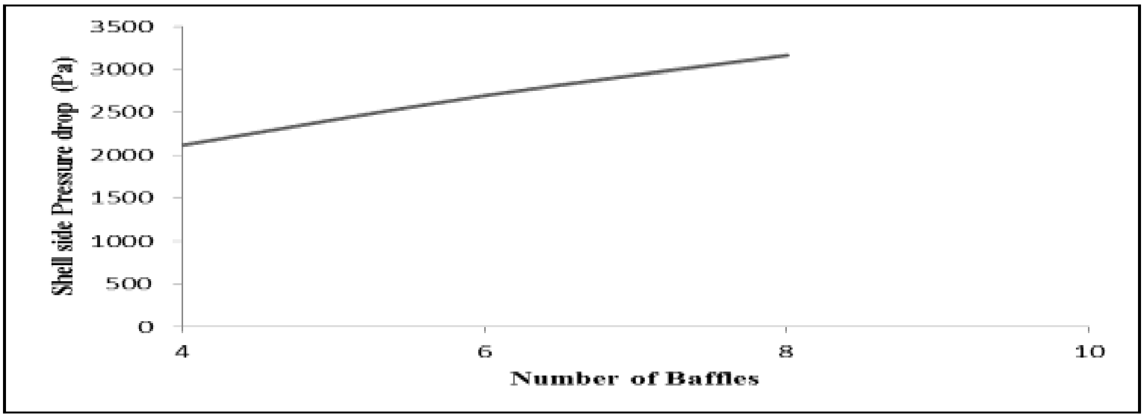


Figure 18: Shell side pressure drop vs number of baffles

Shell side pressure drop in various cases
The graph 18 demonstrates the variation of pressure drop in shell side with the number of baffles. As the number of baffles increases, shell side pressure drop increases. If pressure drop increases then required pumping power is also increase.

VI CONCLUSIONS AND SCOPE OF FUTURE WORK

Conclusions

Effect of number of baffles on heat transfer
As the number of baffles increasing for same length of shell, then spacing between the baffles are decreasing. Since the spacing between the baffle is less so the area of recircula- tion is less and high turbulence is developed. In high turbulence region, heat transfer rate is also high. Another point of interest is that due to increase in number of baffles, fluid has to cover more distance in the shell so the effective heat transfer area increases which is

results in high heat transfer rate. Heat transfer is 37.414 % more in case of 8 baffles as compared to 4 baffles.

Effect of number of baffles on shell side pressure drop

As the number of baffles increasing, pressure drop in shell side increases. Since increasing in number of baffles means decreasing the space between baffles so the path for fluid flow becomes narrow. When fluid passes through narrow path, its pressure decrease and kinetic energy increase. So pressure drop increases with increase in number of baffles. As the pressure drop increase pumping power required to maintain the flow is also increases. Pressure drop is an adverse phenomenon which should be taken into consideration while designing the shell and tube heat exchanger. Pressure drop in shell side is 49.34% in case of 8 baffles as compared to 4 baffles.

Scope of future work

(a) Optimization of baffle spacing, to reduce the pressure drop in shell side and increase the heat transfer rate.
(b) Optimization for baffle cut.

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