A Review of Heat Transfer Studies for Shell & Tube Heat Exchangers

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Abstract: **A review of shell and tube heat exchanger with different objective were presented in this like helical baffle and study the flow and temperature field inside the shell using ANSYS software tools, a nonlinear system of integro-partial differential algebraic equations, modeling by using CATIA V5 software, thermal and hydraulic analysis , overall heat coefficients. Two methods were applied in the suggested design model, Kern and Bell-Delaware, in addition to the step by step technique.**

Keywords: **shell, tube, heat transfer, turbulence etc.**

Introduction:

B.Chandra sekhar , D.Krishnaiah , F.Anand Raju [1] presented in their technical paper the numerical analysis of thermal sizing of multi tube pass shell and tube heat exchanger was obtained. The thermal sizing of multi tube pass shell and tube Heat Exchanger his desired with the bell manual method and for the same the numerical Analysis have been carried out based on the prescribed pressure drop criteria. The analysis of shell and tube Heat Exchanger and performance of evaluation is presently established technique used in power plant industry. In this paper the numerical investigation on tube side water flow pressure drop variations for Multi tube pass shell and tube heat Exchanger in addition to heat transfer coefficients are to be obtained. The pressure drop values for 1,2,4,6 tube pass shell and tube heat Exchanger are obtained by using ―C ―PROGRAMING and compared with Bell Manual Method values.

Anil Kumar Samal [2] presented in their technical paper shell and tube heat exchanger was the most common type heat exchanger widely use in oil refinery and other large chemical process, because it suits high pressure application. The process in solving simulation consists of modeling and meshing the basic geometry of shell and tube heat exchanger using CFD package ANSYS 13.0. The heat exchanger contains 7 tubes and 600 mm length shell diameter 90 mm. The helix angle of helical baffle will be varied from 00 to 200. In simulation will show how the pressure vary in shell due to different helix angle and flow rate. The flow pattern in the shell side of the heat exchanger with continuous helical baffles was forced to be rotational and helical due to the geometry of the continuous helical baffles, which results in a significant increase in heat transfer coefficient per unit pressure drop in the heat exchanger.

Franco Evangelista [3] presented in their technical paper dynamics of steam heated shell and tube heat exchangers are governed by a nonlinear system of integro-partial differential algebraic equations (IPDAE). An approximate solution was obtained by the characteristic, Laplace transform and difference equation methods (CLD) which is valid for generic non-zero initial conditions and any combination of stepwise inputs. It compares well with rigorous solutions (FEM). The results obtained are particularly useful in the design of analog and digital controllers.

Sandeep K. Patel, Alkesh M. Mavani [4] presented in their technical paper to design the shell and tube heat exchanger which was the majority type of liquid –to- liquid heat exchanger. General design considerations and design procedure are also illustrated in this paper. In design calculation HTRI software was used to verify manually calculated .

B.Jayachandriah V.Vinay Kumar [5] presented in their technical paper shell and tube heat exchanger the most common type of heat exchanger widely used in oil refineries, automobiles, aerospace applications because it suits for high pressure applications. An attempt was made in this paper is Design of Shell and Tube Double Pass Heat Exchanger with helical baffle and comparing with segmental baffle using kern method. Then the modelling is done by using CATIA V5 software. The model contains 7 tubes each having a diameter of 20mm, Length 500mm and Inner Diameter of Shell is 90mm, Length 600mm. The material of the Shell is made up of Steel AISI 1010, Tube as Copper and baffle as Aluminum. The angle of baffle is varying from 0 to 30 degrees .

The results are drawn the thermal and hydraulic analysis of a (Continuous Helical baffled Heat Exchanger) with segmental baffle. It gives us a clear idea that the Overall Heat transfer coefficient was maximum in helixchanger as compared to segmental baffle. The pressure drop decreases with the increase in helix angle. Helix angle of 6 degree better heat transfer than the one with an angle of 18 degree as it expenses pumping cost.

Ali Hussain Tarrad and Ali Ghazi Mohammed [6] presented in their technical paper experimental and theoretical model predictions for thermal and hydraulic design of shell and tube heat exchanger are presented. The tests were carried out at hot fluid temperature range between (40) to (60) C˚ at atmospheric pressure for volumetric flow rates ranged between (800) to (1800) l/hr.The model presented for this object was suggested to be accomplished by using the step by step technique. In this model, the heat exchanger was divided into longitudinal increments along the heat exchanger for both tube and shell sides. The output of each increment for both sides of process and service fluids including the thermal and hydraulic parameters are considered to be the input of the next increment and so on until the final temperature and load of the heat exchanger together with the hydraulic requirements were reached.

The prediction of heat exchanger performance of the present model well agreed with the above mentioned methods. The results of the present model showed a good agreement with the experimental data obtained during this investigation for the performance parameters considered in the model. The predicted values of the overall heat transfer coefficient showed a divergence ranged between (15%) and (17%) for service fluid flow rates of (850) and (1000) l/hr respectively.

Usman Ur Rehman [7] presented in their technical paper an un-baffled shell-and-tube heat exchanger design with respect to heat transfer coefficient and pressure drop was investigated by numerically modeling. The heat exchanger contained 19 tubes inside a 5.85m long and 108mm diameter shell. The flow and temperature fields inside the shell and tubes are resolved using a commercial CFD package considering the plane symmetry. A set of CFD simulations was performed for a single shell and tube bundle and is compared with the experimental results. The results are found to be sensitive to turbulence model and wall treatment method. It was found that there are regions of low Reynolds number in the core of heat exchanger shell. Thus, k□! SST model, with low Reynolds correction, provides better results as compared to other models. The temperature and velocity profiles are examined in detail. It was seen that the flow remains parallel to the tubes thus limiting the heat transfer. Approximately, 2/3rd of the shell side fluid was bypassing the tubes and contributing little to the overall heat transfer. Significant fraction of total shell side pressure drop was found at inlet and outlet regions. Due to the parallel flow and low mass flux in the core of heat exchanger, the tubes are not uniformly heated. Outer tubes fluid tends to leave at a higher temperature compared to inner tubes fluid. Higher heat flux was observed at shell's inlet due to two reasons. Firstly due to the cross-flow and secondly due to higher temperature difference between tubes and shell side fluid. On the basis of these findings, current design needs modifications to improve heat transfer.

Amarjit Singh and Satbir S. Sehgal [8] presented in their technical paper the experimental analysis was performed on the shell-and-tube type heat exchanger containing segmental baffles at different orientations. In the current work, three angular orientations (θ) 0, 30, and 60 degrees of the baffles were analyzed for laminar flow having the Reynolds number range 303–1516. It was observed that, with increase of Reynolds number from 303 to 1516, there was a 94.8% increase in Nusselt number and 282.9% increase in pressure drop. Due to increase of Reynolds number from 303 to 1516, there is a decrease in nondimensional temperature factor for cold water (ω) by 57.7% and hot water (ξ) by 57.1%, respectively.

Mohammad Reza Saffarian [9] presented in their technical paper shell and tube heat exchanger with simple baffle has been investigated by computational fluid dynamics software. This heat exchanger includes 37 tubes and 4 baffles inside a shell with the length of 5.85 m and the diameter of 200 mm. Fields of flow and temperature were analyzed inside the shell and the tubes using software. By investigations done on turbulence models, the k-ω SST model was used that provides better results. Three meshes, coarse, medium and fine were investigated and it was shown that aspect ratio has no significant effect. Thereby, finally a mesh including 4.2 million elements was used.

Profiles of temperature and velocity due to results of the model were compared with experimental data and it had an acceptable adaptation. It is seen that flow due to the existence of baffle does not remain in parallel with tube. As a result, the heat transfer level improves and thus the heat transfer increases

Ajeet Kumar Rai and Mustafa S Mahdi [10] presented in their technical paper a method for thermal-hydraulic design of single phase liquid to liquid shell and tube heat exchanger was established based on Tinker method. Modification suggested by Kern and Kakac are also incorporated. A computer program has been developed to ease the design procedure. The program determines the overall dimensions of the shell, the tube bundle, and optimum heat transfer surface area required to meet the specified heat load by utilizing the allowable shell-side pressure drop and other optimum parameters like fixed tube side velocity and fixed baffle cut. The capability of the proposed model was verified through a case study of a shell and tube heat exchanger used in a locomotive for cooling of the lubricating oil of the engine. The design shows a comparable result with the case study with deviation of 10%.

Orlando Duran et al [11] presented in their technical paper to develop and test a model of cost estimating for the shell and tube heat exchangers in the early design phase via the application of arti¯cial neural networks (ANN). An ANN model can help the designers to make decisions at the early phases of the design process. With an ANN model, it is possible to obtain a fairly accurate prediction, even when enough and

adequate informa-tion is not available in the early stages of the design process. This model proved that neural networks are capable of reducing uncertainties related to the cost estimation of a shell and tube heat exchangers.

M. Thirumarimurugan et al [12] presented in their technical paper an experimental investigation on comparative heat transfer study on a solvent and solution were made using 1-1 Shell and Tube Heat Exchanger. Steam is the hot fluid, whereas Water and Acetic acid- Water miscible solution serves as cold fluid. A series of runs were made between steam and water, steam and Acetic acid solution. In addition to, the volume fraction of Acetic acid was varied and the experiment was held. The flow rate of the cold fluid was maintained from 120 to 720 lph and the volume fraction of Acetic acid was varied from 10-50%. Experimental results such as exchanger effectiveness, overall heat transfer coefficients were calculated. A mathematical model was developed for the outlet temperatures of both the Shell and Tube side fluids and was simulated using MATLAB program. The model was compared with the experimental findings and found to be valid.

Vindhya Vasiny Prasad Dubey et al [13] presented in their technical paper extensive thermal analysis of the effects of severe loading conditions on the performance of the heat exchanger. To serve the purpose a simplified model of shell and tube type heat exchanger has been designed using kern's method to cool the water from 55 to 45 by using water at room temperature. Then we have carried out steady state thermal analysis on ANSYS 14.0 to justify the design. After that the practical working model of the same has been fabricated using the components of the exact dimensions as derived from the designing. We have tested the heat exchanger under various flow conditions using the insulations of aluminium foil, cotton wool, tape, foam, paper etc. We have also tested the heat exchanger under various ambient temperatures to see its effect on the performance of the heat exchanger.

Moreover we have tried to create the turbulence by closing the pump opening and observed its effect on its effectiveness. All these observations along with their discussions have been discussed in detail inside the paper.
Satyam Bendapudi et al [14] presented in their technical paper modeling the dynamics of shell-and-tube heat-exchangers is an important step in developing dynamic system models of liquid chillers that are used for studying transient system performance. Existing literature on the subject is limited and much of what exists uses either a lumped parameter approach or a finite volume approach for the shell-and-tube heat-exchangers. The lumped parameter approach was simplistic and provides neither spatial detail nor sufficient accuracy in predicting exit conditions. The finite volume approach provides extensive spatial detail but at significant computational expense. A third alternative, known as the moving-boundary approach, has thus far only been used for refrigerant-in-tube coils. It has the potential for fast execution due to the reduced number of equations as compared to the finite-volume method, while retaining some spatial detail. This paper details the formulation of shell-and-tube evaporators and condensers using the moving-boundary approach and presents comparative results of model execution with a finite-volume approach. Both formulations are developed to capture start-up and load change transients. The moving-boundary formulation has the ability to handle the discontinuities associated with phase-boundaries exiting and entering the heat-exchanger during transient operation. A significant saving in execution time was shown over the finite-volume approach with comparable accuracy.

B.Dinesh and E.Sivaraman [15] presented in their technical paper a shell and tube heat exchanger was a class of heat exchanger designs seen most common type of heat exchanger in oil refineries and other large chemical processes, and is suited for higher-pressure applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. In this paper, the mathematical modelling of Shell and tube heat exchanger is developed and transfer function is obtained using process reaction curve method. The PID controller for a shell and tube heat exchanger is designed using Z-N tuning method. The shell and tube heat exchanger is modeled using fuzzy c-means algorithm (FCM) and its output is compared with thatof actual shell and tube heat exchanger output.
Kirubadurai.B at el [16] presented in their technical paper Heat exchanger was a device which provides a flow of thermal energy between two or more fluids at different temperatures. There are many problems created in the segmental heat exchanger during and after the work. The major causes of this problem is the geometry of heat exchanger, type of fluid used, type of material etc., The purpose of this work is to design the shell and tube heat exchanger which is one among the majority type of liquid –to – liquid heat exchanger. Since the important design parameters such as the pitch ratio, tube length, and tube layer as well as baffle spacing has a direct effect on pressure drop and effectiveness, they are considered to be the key parameters in this work. General design consideration and design procedure are also illustrated in this work. The analysis of orifice baffle and convergent divergent tube in a shell and tube heat exchanger are experimentally carried out. The newly designed heat exchanger obtained a maximum heat transfer coefficient and a lower pressure drop. From the numerical experimentation, the result shows that the performance of heat exchanger increases in modified baffle and tube than the segmental baffle and tube arrangement
Ranj Sirwan et al [17] presented in their technical paper an optimization of heat transfer for smooth circular tube used in an evaporator of the ammonia-water absorption cooling system has been carried out to estimate minimum outlet water temperature and maximum heat flux. The tube diameter ranges from 7 to 13 mm and length ranges from 0.5 to 1.2 m, has been varied to study the effects. The numerical analysis was performed by using the finite elements commercial code. The optimization result has shown that 7 mm diameter and 1.2 m length has given the minimum water temperature of 8.3 oC at the outlet with maximum heat flux of 16193 W/m2.
Mohammed Rabeeh V. and Vysakh S.[18] presented in their technical paper design of shell and tube heat exchangers are done by formulating a standard procedure where the parameters required for building a HX is calculated using numerical method until the dimensions satisfy the condition for maximum overall heat transfer coefficient, this was done using a MATLAB code in which the calculations are iterated by varying the TEMA specified values for tube length and tube outer diameter. The output of this calculation is proposed to be the effective parameters for design of shell and tube heat exchanger for given boundary conditions. Energy balance over the heat exchanger for the designed HX was completed using partial differential equations, which was solved using second order Runge-Kutta method. Since Runge- Kutta method is very robust and efficient, so thermal diffusion term is not included in the energy balance equation. By plotting a temperature v/s tube length graph in MATLAB using the energy balance differential equation and analyzing the same, time required for the shell and tube heat exchanger to reach a steady state condition I was obtained. The present work proposes a standard steps to design and analyze the working and performance of a shell and tube heat exchanger.
Hari Haran et al [19] presented in their technical paper a simplified model for the study of thermal analysis of shell-andtubes heat exchangers of water and oil type was proposed..Shell and Tube heat exchangers are having special importance in boilers, oil coolers, condensers, pre-heaters. They are also widely used in process applications as well as the refrigeration and air conditioning industry.The robustness and medium weighted shape of Shell and Tube heat exchangers make them well suited for high pressure operations. In this paper we have shown how to done the thermal analysis by using theoretical formulae for this we have chosen a practical problem of counter flow shell and tube heat exchanger of water and oil type, by using the data that come from theoretical formulae we have design a model of shell and tube heat exchanger using Pro-e and done the thermal analysis by using ANSYS software and comparing the result that obtained from ANSYS software and theoretical formulae. For simplification of theoretical calculations we have also done a C code which is useful for calculating the thermal analysis of a counter flow of water-oil type shell and tube heat exchanger.

Ahilan, S. Kumanan, N. Sivakumaran [20] presented in their technical paper Heat exchanger was a device in which heat was transferred from one medium to another across a solid surface. The performance of heat exchanger deteriorates with time due to fouling on the heat transfer surface. It was necessary to assess periodically the heat exchanger performance, in order to maintain at high efficiency level. Industries follow adopted practices to monitor but it was limited to some degree. Online monitoring has an advantage to understand and improve the heat exchanger performance. In this paper, online performance monitoring system for shell and tube heat exchanger was developed using artificial neural networks (ANNs). Experiments are conducted based on full factorial design of experiments to develop a model using the parameters such as temperatures and flow rates. ANN model for overall heat transfer coefficient of a design/ clean heat exchanger system was developed using a feed forward back propagation neural network and trained. The developed model was validated and tested by comparing the results with the experimental results. This model was used to assess the performance of heat exchanger with the real/fouled system. The performance degradation is expressed using fouling factor (FF), which was derived from the overall heat transfer coefficient of design system and real system. It supports the system to improve the performance by asset utilization, energy efficient and cost reduction in terms of production loss.

Chintan D Patel et al [21] presented in their technical paper the Taguchi method was applied to perform screening of experiments and to identify the important significant parameters which are affecting the efficiency of shell and tube type heat exchanger. The prefix parameters (tube diameter, mass flow rate and pitch length) are used as input variable and the output parameter is maximum temperature difference of shell and tube heat exchanger. Nine different models are made in Solid Works 2012 software and CFX analysis is carried out in ANSYS 12.0. The Minitab 16 software was used for Taguchi analysis. Result obtained from the Taguchi analysis shows that which combination of design parameter gives the minimum outlet temperature of water. The most affected parameter on temperature of water from tube diameter, pitch length and mass flow rate was found out from Taguchi analysis. Also the Taguchi results are validated by performing experiment for L9 array.

B.Jayachandriah and K. Rajasekhar [22] presented in their technical paper tubular Heat exchangers can be designed for high pressures relative to environment and high-pressure differences between the fluids. Tubular exchangers are used primarily for liquid-to-liquid. An attempt was made in this paper is for the Design of shell and tube heat exchangers by modeling in CATIA V5 by taking the Inner Diameter of shell was 400 mm, length of the shell was 700 mm and Outer diameter of tube is 12.5mm, length of Tube is 800mm and Shell material as Steel 1008, Tube material as Copper and Brass. By using modeling procedure Assembly Shell and Tube with water as medium was done. By using ANSYS software, the thermal analysis of Shell and Tube heat exchangers is carried out by varying the Tube materials. Comparison was made between the Experimental results, ANSYS. With the help of the available numerical results, the design of Shell and Tube heat exchangers can be altered for better efficiency.

Hetal Kotwal, and D.S PATEL [23] presented in their technical paper focuses on the various researches on CFD analysis in the field of heat exchanger. Different turbulence models available in CFD tools that is Standard k-ε model, k- ε RNG model, Realizable k- ε, k-ω and RSM model in conjunction with velocity pressure coupling scheme and have been adopted to carry out the simulation. The steady increase in computing power has enable model to react for multi phase flows in realistic geometry with good resolution. The quality of the solution has proved that CFD was effective to predict the behavior and performance of heat exchanger

N. GowthamKumar [24] presented in their technical paper the thermal design of multi-stream heat exchangers of the shell and tube type is considered which are used in high temperature processes and their application was extrapolated to above temperature processes. When the characteristic length scales of the channels are reduced at a constant pressure drop, the effectiveness exhibits a maximum due to axial heat conduction in the pipe material. The point of maximal effectiveness is found to correspond to a maximal thermal power density and thus to the minimal volume required for obtaining a given effectiveness. In shell & tube heat exchanger (Water & oil) thermal constants are calculated for finding Reynolds number, Nusselt number, Effectiveness & NTU by varying mass flow rate along with change of water inlet temperature again calculation of LMTD and area required from with changing Fouling factor of oil, check for variation in Heat transfer coefficient of oil & Overall heat transfer coefficient. And the calculation results are verified based on thermal analysis carried on model heat exchanger as per specification in CATIAV5 and same is analyzed in Ansys.

A.GopiChand et al [25] presented in their technical paper a simplified model for the study of thermal analysis of shell-and-tubes heat exchangers of water and oil type was proposed..Shell and Tube heat exchangers are having special importance in boilers, oil coolers, condensers, pre-heaters. They are also widely used in process applications as well as the refrigeration and air conditioning industry. The robustness and medium weighted shape of Shell and Tube heat exchangers make them well suited for high pressure operations. In this paper we have shown how to done the thermal analysis by using theoretical formulae for this we have chosen a practical problem of counter flow shell and tube heat exchanger of water and oil type, by using the data that come from theoretical formulae we have design[2] a model of shell and tube heat exchanger using Pro-e and done the thermal analysis by using Floefd software and comparing the result that obtained from Floefd software and theoretical formulae. For simplification of theoretical calculations we have also done a Matlab code which is useful for calculating the thermal analysis of a counter flow of water-oil type shell and tube heat exchanger.

Sandeep M, U Sathishkumar [26] presented in their technical paper different cross section bundle arrangements such as triangle, rectangular and round for a shell and tube heat exchanger computationally was presented. Ultimately, relationship between pressure drop and heat transfer is evolved for different cross section shape in a counter flow model shell and tube heat exchanger. The bundle cross section contribute towards pressure drop for same segmental baffle arrangement. This pressure drop can leads to structural damage of heat exchanger parts. The paper aims at understanding the effect of pressure drop caused due to three different bundle arrangements in shell and tube heat exchanger

Rahul Singh et al [27] presented in their technical paper a heat exchangers of water was proposed with simplified model for the study of thermal analysis of shell-and-tubes. Shell and Tube heat exchangers are having special significance in boilers, Power plants, condensers, turbines. This research work focus on computational fluid dynamics analysis of shell and tube heat exchanger. In this research work we have shown how the heat transmission rate change by changing the flow of water it will be counter flow or parallel flow with varying its molding design. The 3D modeling of the shell and tube heat exchanger is designed in INVENTER PROFESSIONAL and its analysis was done in ANSYS-FLUENT 14.5 and 15. We make the design better by providing the fin of circular shape with baffles and without baffles making the flow counter and parallel. During the 400mm segment of the shell we provide 84 fins and 4 baffles with 7 tubes which make the heat exchanger performance better than ordinary shell and tube Heat exchanger. The Results Shows that the Maximum heat transmission take place in the circular fin with baffle having the counter flow of the water, which provide more time for the flow of water for heat transmission in a wavy form and large surface area for the heat dissipation for the cooling of water.

Sachin k.Patel., A.R.Patel [28] presented in their technical paper the shell and tube heat exchanger was widely used in industries as a chillers plant for transfer waste heat from the injection molding machine to the cooling water from improve the effectiveness of the injection molding machine. the transformation of the waste heat from injection molding machine to the cooling water dependent on the heat exchangers. To increase the heat exchanger capacity of heat exchanger was invite the optimization problem which seeks to identify the best parameter combination of heat exchangers. In order to tackle such an optimization problem in present work the Taguchi method was applied to perform screening of experiments and to identify the important significant parameters which are affecting the efficiency of shell and tube type heat exchanger. The prefix parameters (tube diameter, mass flow rate and pitch length) are used as input variable and the output parameter is maximum temperature difference of shell and tube heat exchanger..Result obtained from the Taguchi analysis shows that which combination of design parameter gives the minimum outlet temperature of water. The most affected parameter on temperature of water from tube diameter, pitch length and mass flow rate was found out from Taguchi analysis. Also the Taguchi results are validated by performing experiment for L9 array.

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