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Application of Pinch Technology in Refrigerator Condenser Optimization –A Review

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Abstract* - In the refrigerator condenser the study of condenser is main objective for the improvement of system output. Pinch technology and computational fluid dynamics is key for study the condenser and enhance the better option for the new design. Current design of condenser working effectively but certain modification can be done using pinch technology and that modification can be study on computational fluid dynamics using boundary conditions and models. By finding pinch point of condenser further study must be done for prediction of pressure drop, thermal analysis, velocity analysis compare to existing design. Finding the effective design of condenser using pinch technology and CFD is beneficial for overall cost and material saving.
***Keywords* – Refrigerator Condenser, Pinch Technology, Computation Fluid Dynamics**

I. INTRODUCTION

As the demand of refrigeration is increase we must study on system to optimized the condenser design and reduce the energy cost and material cost. With development of computer technology, simulation software it is possible to optimized the result. In this field simulation and optimization is prime task to perform. At present the work about design, calculation and modeling of refrigerator condenser has been done but in traditional way without considering optimal result and energy and material cost. Pinch technology is method for calculating optimal result and can extract extra amount of condenser length so material saving. Pinch technology is minimum temperature difference in any heat exchanger and calculate minimum energy target by considering data of hot and cold stream. Graph of temperature and enthalpy is plotted on axis and pinch point can be calculated. Pinch technology mainly developed in early 70es by linnhoff and co-worker who developed a graphical method to calculate minimum energy requirement of process and design the heat recovery heat exchanger. Now a day pinch technology is great tool to analysis the heat exchanger. Computational fluid dynamic (CFD) is branch of fluid mechanics that uses the numerical analysis and algorithm to solve and analyze the problem that involve fluid flow. Computational fluid dynamics is use to analysis the new design of heat exchanger of pinch technology. This study uses pinch technology analysis to save energy and material for refrigerator condenser.

II. PINCH TECHNOLOGY

Pinch technology is a methodology for minimizing energy consumption by calculating feasible energy target and achieve them by optimizing heat recovery system, energy supply method and process operating condition[1]. Pinch point can be obtain by plotting combine graphs between temperature and enthalpy of hot stream and cold stream called as composite curve and the curve slow the data for individual process recovery slow on grand composite curve. The first law of thermodynamics provide the energy equation for calculating the enthalpy change in the stream passing through heat exchanger. The second law determine the direction of heat flow that is, heat energy may only flow in the direction of hot to cold. In heat exchanger unit neither hot stream cool below cold stream supply temperature and nor a cold stream can be heated to the temperature more than supply temperature of hot stream. In practice the hot stream can only be cooled to a temperature define by 'temperature approach' of heat exchanger. Temperature approach is minimum allowable temperature difference (DTmin) in temperature profile for heat exchanger unit. The temperature level at which DTmin observed in the process is known as "pinch point". It is use to identify energy cost and heat exchanger design, capital cost and recognizing pinch point[2] [3] [4].

III. COMPUTATIONAL FLUID DYNAMICS

Computational Fluid Dynamics, abbreviated as CFD, uses different numerical methods and a number of computerized algorithms in

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order to solve and analyze problems that involve the flow of fluids. The calculations required simulating the interaction of fluids with surfaces defined by boundary conditions, and initial conditions are done by the ANSYS Fluent v14.5. The Navier-Stokes equations form the basis of all CFD problems. Two equation models are used for the simulations, and different models. Turbulence is created because of the unstable nature of the fluid flow. The flow becomes turbulent for higher Reynolds number. In this model the k-ε (turbulent kinetics energy "k" and the turbulent dissipation "ε") model is used. Computational Fluid Dynamics Modeling CFD provides numerical approximation to the equations that govern fluid motion. Application of the CFD to analyze a fluid problem requires the following steps. First, the mathematical equations describing the fluid flow are written. These are usually a set of partial differential equations. These equations are then discredited to produce a numerical analogue of the equations. The domain is then divided into small grids or elements. Finally, the initial conditions and the boundary conditions of the specific problem are used to solve these equations. The solution method can be direct or iterative. In addition, certain control parameters are used to control the convergence, stability, and accuracy of the method. All CFD codes contain three main elements: (1) A pre-processor, which is used to input the problem geometry, generate the grid, and define the flow parameter and the boundary conditions to the code. (2) A flow solver, which is used to solve the governing equations of the flow subject to the conditions provided. (3) A post-processor, which issued to massage the data and show the results in graphical and easy to read format [5] [6] [7].

IV. METHODOLOGY

The combine study of pinch technology and computational fluid dynamics for the refrigerator condenser gives the idea about how to optimize the current heat exchanger design, material, area and cost.

PINCH TECHNOLOGY AND CFD
Identify hot, cold and utility stream.
Thermal data extraction for process stream.
Selection of DTmin value.
Construction of grand composite curve.
Estimate energy and capital cost.
Design of heat exchanger (condenser).
Study of basic design of condenser on CFD.
Study of condenser design consists of Pinch point on CFD.
Study the change in parameter on new design (CFD).
Optimized solution for condenser.

In designing the condenser it is very important to process study of the pinch analysis to analyze the process well. In first step we have to study on hot, cold and utility data and get the temperature of all stream and heat duties of process stream requiring energy transfer. By the data it is possible to identify the current energy situation of all stream, supply temperature, target temperature, heat capacity flow rate, enthalpy change and heat balance flow sheet can be observe. Selection of DTmin value from second law of thermodynamics that prohibits any temperature crossover between hot and cold stream so minimum heat transfer driving force must always be allow for feasible heat transfer design thus the temperature of hot and cold stream at any point in exchanger must always have minimum temperature difference (DTmin). Construction of curve, curve plotted against temperature and enthalpy known as composite curve. Heat availability in process is hot composite curve and heat demands in process are cold composite curve. Heat capacity represent on T-H curve. Grand composite curve shows the variation of heat supply and demand within the process in this, designer can find out which utility can be used. Once the DTmin is chosen, hot and cold utility can be find out and if cost of each utility is known then total energy cost can be find out. Capital cost depends on number of exchanger, overall network area. Pinch technology tells us about minimum number of heat exchanger to be predicted prior to detail design. Hence getting the require design of condenser by using pinch technology [1] [2]. To analyze the nature and design of condenser we must require simulation software that is CFD. The basic design of condenser is use for the analysis of refrigerant flow in condenser. Study of condenser is under ANSYS 14.5, FLUENT AND CFX. By using pinch technology we get the optimized size of condenser and now we study the simulation and behaviors of flow of refrigerant in this new design. So the difference in parameter and flow study of both design of condenser we can evaluate the best design of condenser using pinch technology and CFD [5] [7].

V. LITERATURE REVIEW

B.linhoff and E.Hindmarsh, 1983 [1] presented the pinch design method for heat exchanger networks. The method is the first to

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combine sufficient simplicity to be used by hand with near certainty to identify “best” designs, even for large problems. “Best” designs feature the highest degree of energy recovery possible with a given number of capital items. Moreover, they feature network patterns required for good controllability, Plant layout, intrinsic safety, etc. The heuristic approach was developed for performing the pinch analysis for the process plants design.

S. Ahmad, B. Linnhoff and R. Smith, 1990 [2] presented a procedure for the design of near-optimum cost heat exchanger networks. The procedure is based on setting targets for capital and energy costs and optimizing these targets prior to design. The authors extends the model of capital cost to allow for: exploiting differences in heat transfer coefficients for reduced network area, a non-linear exchanger cost law, non counter current heat exchangers, non-uniform materials of construction, pressure ratings and exchanger types in the network. Using these extensions both targeting and design for minimum capital cost are considered. This technique is particularly useful for identifying and screening the effects of different exchanger specification when locating neat optimal networks.

B. Linnhoff and A. R. Eastwood, 1997 [3], at the University of Man operating conditions. It reduces the annual energy cost by 5.6%.In order to achieve it, the capital investment is necessary but the annual cost saving will be enough to recover the cost in less than one year.

Pekka Ruohonen and PekkaAhtila2010 [4] analyzed the mechanical pulp and paper mill using the advanced composite curves. A mechanical pulp and paper mill is analyzed using advanced composite curves. It is a graphical pinch-based approach that takes into account the existing heat exchanger network and the utilities actually used at the mill. The possibilities of making a cost-effective heat exchanger retrofit in an operating mechanical pulp and paper mill are discussed. This study also shows that the advanced composite curves can be used to describe the amount of no isothermal mixing taking place in the process.

P. Bhramara, K. V. Sharma and T. K. K. Reddy 2009 [5] Pressure drop prediction is especially important for condensers because the local condensing temperature is a function of local pressure, affecting the mean temperature difference in the heat exchanger. Two phase flow is treated as a single phase pseudo fluid with average properties of liquid and vapor using homogeneous model. The pressure drop of refrigerants under two phase flow conditions inside the tube are evaluated using three different models of dynamic viscosity. There is a noticeable variation in the pressure gradient calculated from the three models of average viscosity at a particular quality at low mass flux and the variation decreasing with increase of mass flux. Pressure gradient obtained by all the three models particularly that of McAdam’s and Dukler’s models tend to converge with the increase of mass flux. This is due to the effect of mass flux being dominant compared to that of average viscosity on pressure gradient at high mass flux. The difference in the pressure gradient calculated from the three models of viscosity reduces for high saturation pressure compared to that of low saturation pressure of same refrigerant, R134a. This is due to the average dynamic viscosity obtained using Dukler’s and McAdams models are nearly same particularly at high saturation temperatures and for high pressure refrigerants, R22 and R407C even at low condensation temperatures.

Shengchun Liu*, Yan Huo, Zhaowei Liu, Lan Li, Jinghong Ning 2015 [6] Condensation process of steam has been successfully modeled by applying a user defined function (UDF) added to the commercial computational fluid dynamics (CFD) package. By analyzing the corresponding condensate contours and the curves of local heat transfer coefficient, The relationships between condensation heat transfer coefficient and various parameters of R245fa inside horizontal tube are obtained. It shows that the heat transfer coefficient increases by the increase in velocity, condensation temperature and superheat of inlet steam and the decrease in cooling water temperature. By simulation on the process of R245fa condensing inside a horizontal tube and analysis of simulation results, various parameters have great influences on the condensation heat transfer coefficient. The heat transfer coefficient and film thickness have significant changes after the position of 0.3 m. By comparing the different factors on the condensation heat transfer, it can be seen that the ways of influences of cooling water temperature, condensing temperature and steam flow rate on the condensation heat transfer are different. The increasing of team flow rate results in enhanced shear, and condensation film is not stable in the presence of the tube, so film thickness reduces, and heat transfer coefficient increases. The wall temperature decreases or condensing temperature rises, and the temperature difference increases, so that the heat transfer coefficient increases. The heat transfer coefficient of simulation results is close to the model of Wang and Shah. Thus, the model and method of simulation are suitable for process of condensation.

P. Bhramara, V. D. Rao, K. V. Sharma, and T. K. K. Reddy 2008 [7]. The frictional pressure drop predictions based on separated flow model are considered for comparison as the CFD analysis is performed based on the special case of separated flow model. CFD analysis of two phases, single component tube flow is modeled using FLUENT. Average properties of the refrigerants, R134a, R22 and R407C are evaluated using Homogeneous model for each quality. A pseudo single phase fluid is thus considered in the

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CFD analysis. The resulting pressure drop data obtained at adiabatic conditions match well by separated flow correlations. The CFD results match well with Muller – Steinhagen and Heck correlation.

VI. CONCLUSION

From above related literature on pinch technology and computational fluid dynamics we conclude that on current design of heat exchanger (condenser) and after analysis we get new design of heat exchanger which performs better that previous. Energy and material saving, cost effective. In replacement of new design capital investment is necessary and we can also predict the pressure drop in old and new design of condenser. So we can optimize the result of existing and new design condenser by using computational fluid dynamics and pinch technology.

VII. ACKNOLEDGEMENT

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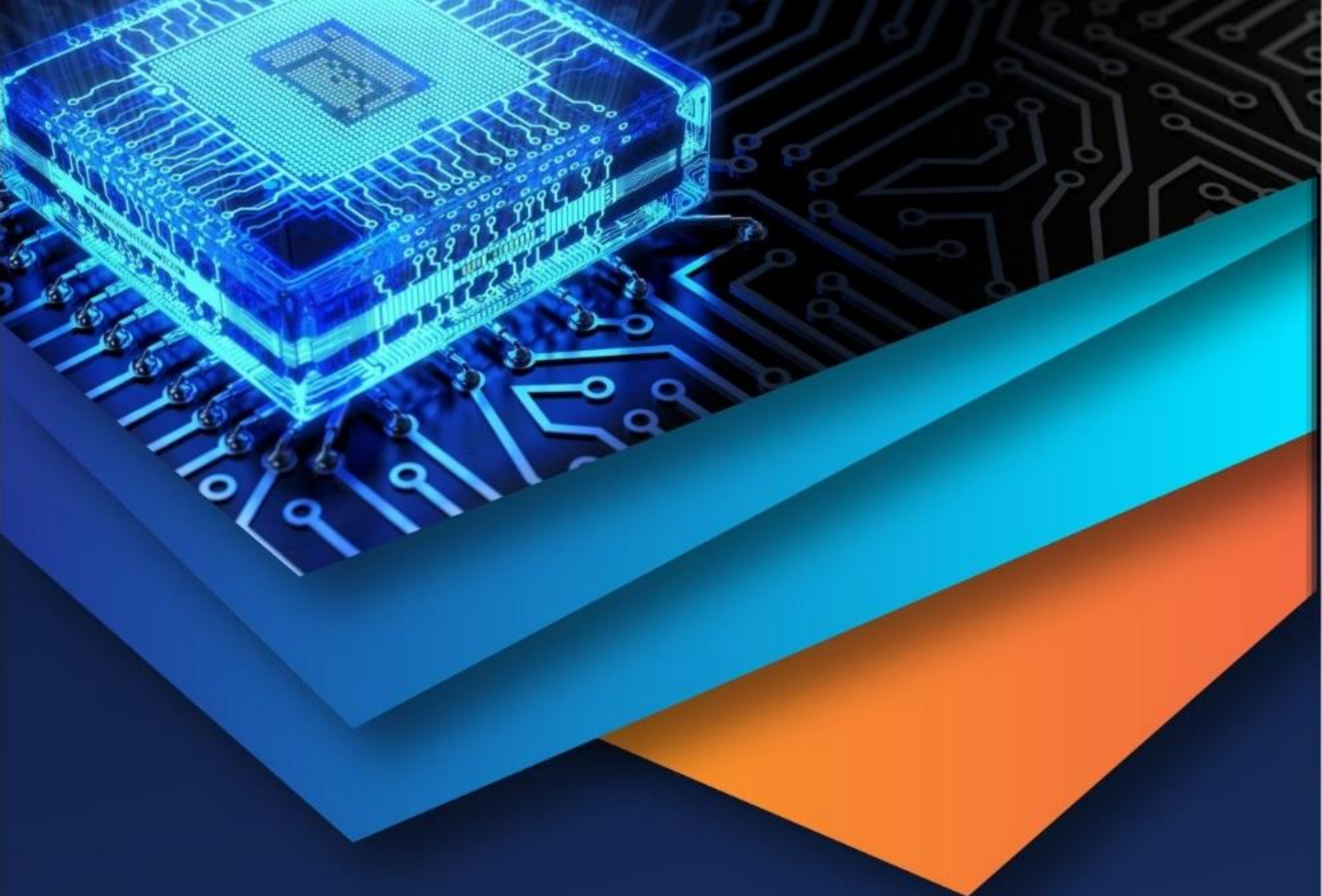

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