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Application of Pinch Technology in Refrigerator Condenser Optimization by Using CFD

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ABSTRACT

Refrigeration is the major application area of thermodynamics, in which the heat is transferred to higher temperature region from a lower temperature region. Refrigerators are the devices which produce refrigeration and the refrigerators which operate on the cycles are called refrigeration cycles. Pinch technology and computational fluid dynamics CFD is key for study the condenser and enhance the better option for new design. Pinch Analysis (also known as process integration, heat integration, energy integration, or pinch technology) is method for minimizing the energy costs of a process by reusing the heat energy in the process streams rather than outside utilities.

KEYWORDS: *Pinch technology, Refrigerators, refrigeration cycles, CFD etc*

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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 In this project our main concern is on straight tube condenser of domestic refrigerator by which we will calculate the heat transfer rate.With development of computer technology, simulation software it is possible to optimize 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.

Objectives

The aim of the project is to Simulation of experimental design by using computational fluid dynamics, Simulation of revise design after finding out pinch point on CFD and comparative analysis of experimental simulated and revise design of condenser.

Literature review

1. **The Chemical engineer resource, "pinch technology: basic for the beginners" (1990)** Prof Bodo linnhoff study on pinch technology for the basic concept of pinch point analysis and give the review on energy conservation. Step which must be follow for analysis is also stated the paper represent a new set of thermodynamically base method that guarantee minimum energy level in design of any heat exchanger network. Pinch analysis often use to represent the application of tool and algorithm of pinch technology for studying industrial process. The core of the process is design with fix flow rate

and the temperature yielding the heat and mass balance for process then design of heat recovery system is completed. Study of all parameter contain in pinch technology and basic provided in this paper.

2. **P. Bhramara et al. (2008)**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 phase, 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 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

Pinch Technology

Pinch technology is a methodology for minimizing energy consumption by calculating feasible energy target and achieves them by optimizing heat recovery system, energy supply method and process operating condition. Pinch Analysis (also known as process integration, heat integration, energy integration, or pinch technology) is method for minimizing the energy costs of a process by reusing the heat energy in the process streams rather than outside utilities. The process requires three pieces of data from each process stream: the heat load (enthalpy) in kW, the source temperature in °C or °F, and the target temperature in °C or °F. The data from all streams are combined in order to create plots of enthalpy against temperature, called composite curves. Four composite curves are needed, curves for the hot and cold process streams, a combined plot of both the hot and cold composite curves, and the grand composite curve. From the combined curve plot we can see the region where the distance between the hot and cold curves is at a minimum this region is called the pinch point.

Computational Fluid Dynamics

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

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.

- Identify hot, cold and utility stream
- Thermal data extraction for process stream
- Estimate energy and capital cost
- Design of heat exchanger
- Study of basic design of condenser on CFD
- Study the change in parameter on new design

Revise design of condenser simulation by using pinch technology upto the location of 40°C.

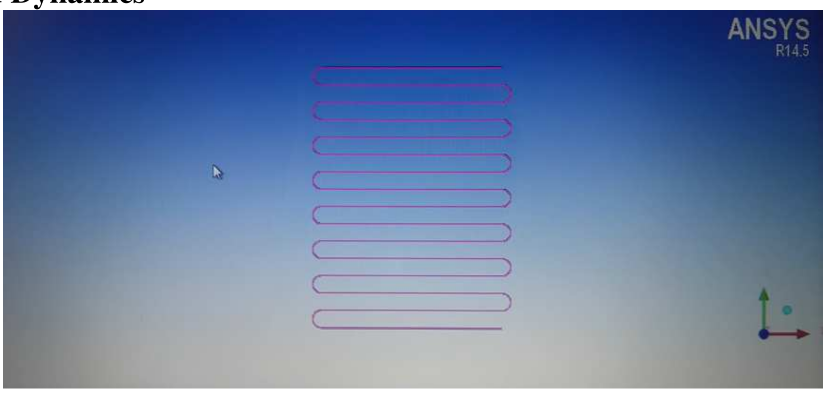

Fig. 1- Revise design upto pinch point

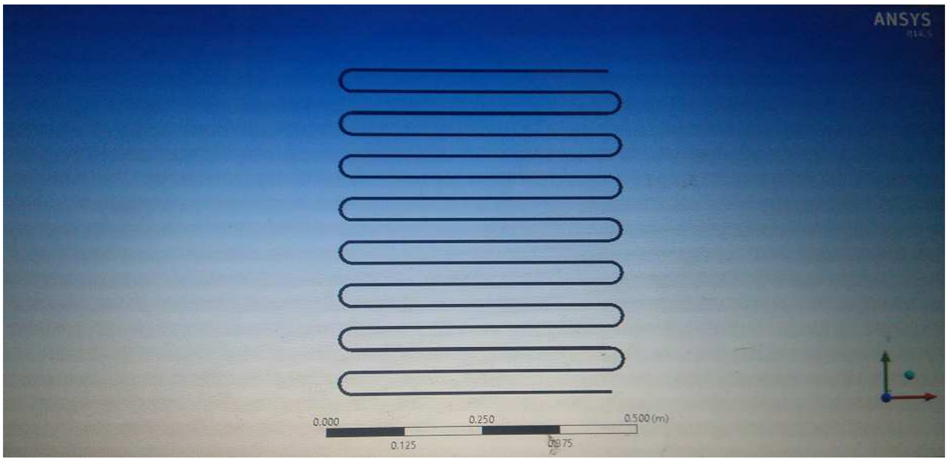

Fig.2- Meshing of pinch design

Meshing of pinch design up to location of pinch point shown in figure 2

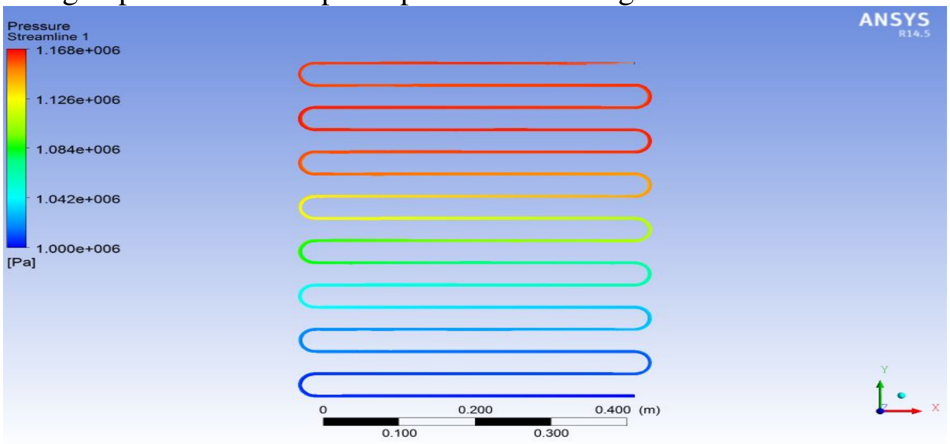

Fig. 3- Pressure drop in condenser

Variation of pressure in pinch design and pressure loss due to bending and multiphase of refrigerant shown in figure 3

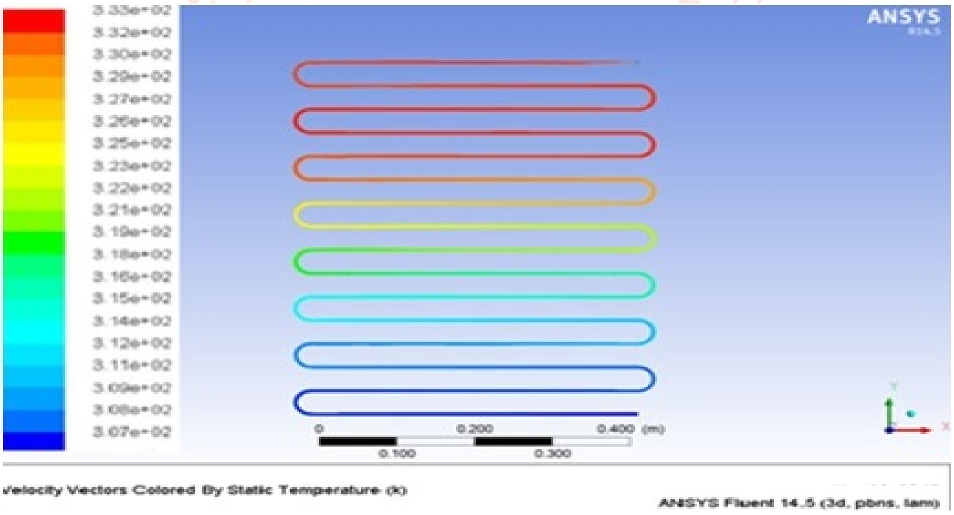

Fig. 4- Temperature drop in condenser

Temperature drop in pinch design up to pinch point shown in figure.4

Comparison and validation

Table 1 Comparing Experimental, Analytical and Pinch value

Sr. no	Experimental value	Analytical value	Pinch value
1.Temperature (°C)	63.1-38.1	60-32	63-34
2.Pressure(bar)	11.5-11.3	11.85-10.23	11.6-10
3.Mass flow rate (kg/sec)	0.18-0.1848	0.148-0.150	0.145-0.151

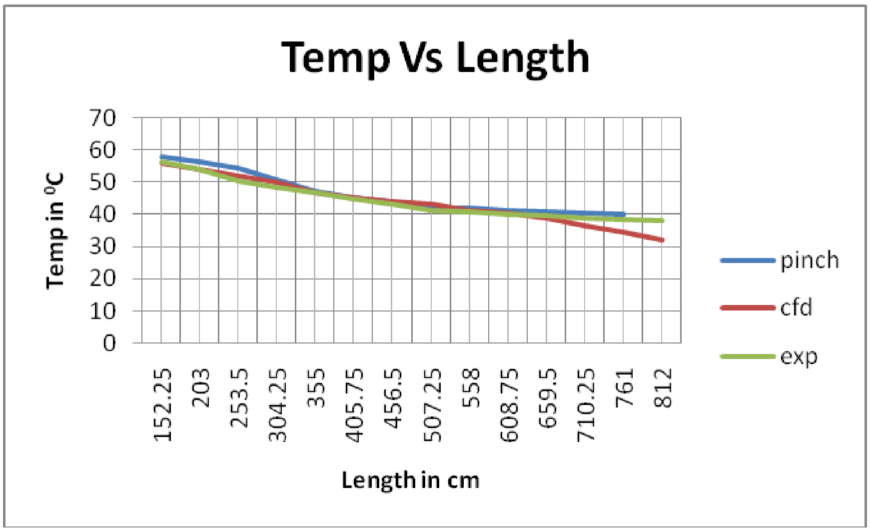

Fig. 5.Comparing experimental, Analytical and Pinch value of temperature verses length of Condenser tube

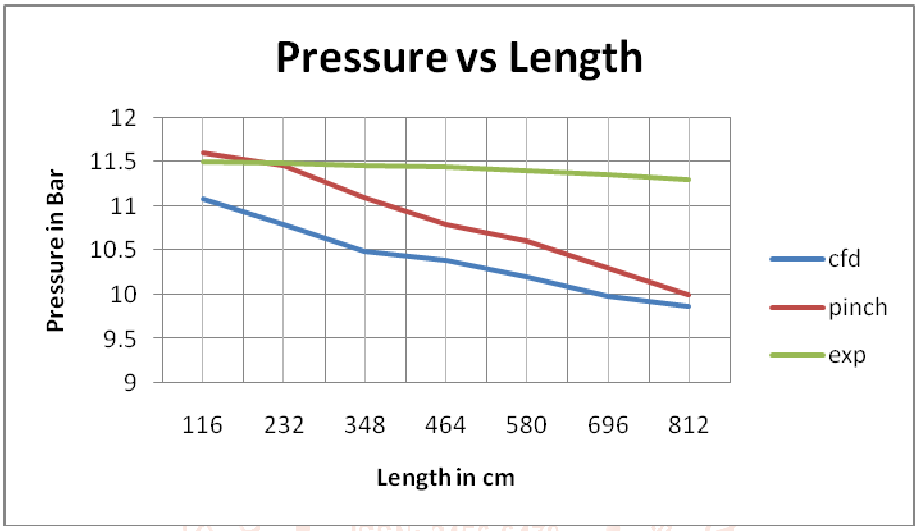

Fig. 6 Comparing Experimental, Analytical and Pinch value of Pressure verses Length of Condenser tube

Conclusion

- Using pinch technology, it is observed that it is observed that length of the condenser can be reduced up to 10cm with the same output of the existing experimental design.
- The material and diameter can easily be altered of condenser by means for condenser effectiveness in Ansys CFD.

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