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Numerical Investigation of Air Cooled Condensers using Different Refrigerants

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ABSTRACT

Condensers are an integral part of refrigeration system. The current research reviews existing work conducted on improving the design and performance of condenser by varying design and operating conditions. The comparative studies between different types of condensers on the basis of COP (coefficient of performance), energy consumption, refrigeration capacity are also presented. The effect of operational parameters and other factors along with development of empirical correlation on performance is also presented.

KEYWORDS: *CFD, Condensers, Refrigerant*

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1. INTRODUCTION

Condenser is an important component of any refrigeration system. In a typical refrigerant condenser, the refrigerant enters the condenser in a superheated state. It is first de-superheated and then condensed by rejecting heat to an external medium. The refrigerant may leave the condenser as a saturated or a sub-cooled liquid, depending upon the temperature of the external medium and design of the condenser. In actual refrigeration systems with a finite pressure drop in the condenser or in a system using a zeotropic refrigerant mixture, the temperature of the refrigerant changes during the condensation process also.

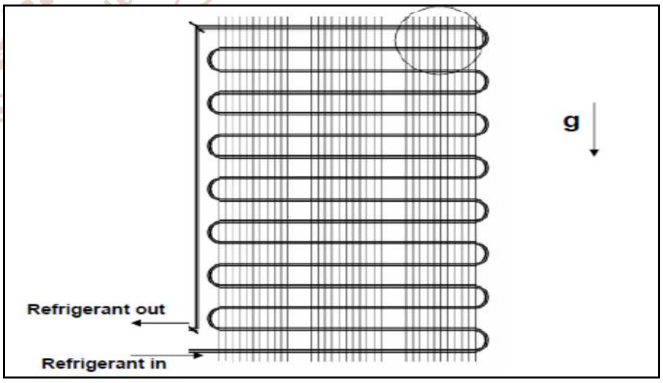

Figure 1: Schematic of a wire-and-tube type condenser used in small refrigeration systems

The finned type condensers are mounted either below the refrigerator at an angle or on the backside of the refrigerator. In case, it is mounted below, then the warm air rises up and to assist it an air envelope is formed by providing a jacket on backside of the refrigerator. The fin spacing is kept large to minimize the effect of fouling by dust and to allow air to flow freely with little resistance. In this design, the condenser tube (in serpentine form) was attached to a plate and the plate was mounted on the backside of the refrigerator. The plate acted like a fin and warm air rose up along it.

2. LITERATURE REVIEW

Ferry (1996) [1] has done a study on treatment of water for controlling the growth of biological organisms specially algae. Formation of algae in stored water is a natural phenomenon which takes nutrients from water. The formed algae flow into the water jackets and water pipes of cooling systems from the tank which are the supply line for cooling water and the above components are choked with an accumulation of biological organisms. This innovative idea relates specifically to control of algae growth in stored water like in cooling systems.

Apart from that, Wu (1986) [2] had invented an improved water-cooled air conditioner where a cooling device to be served as a conventional cooling tower is combined with the evaporator of the air conditioner to form a single unit. This model reduces the cost and also it is easy to install. Some of the work has also been done in the field of improvement of performance and consumption of energy of water-cooled condensers.

As Lee et al (2008) [3] worked on water cooled air-conditioning systems and developed an empirical model for predicting the operational performance and consumption of energy for the use of water-cooled air conditioners whereas other authors tried boosting the thermal performance of an air conditioning system using a cooling water loop and found that the coefficient of performance is significantly increased.

Similarly, Hu et al (2005) [4] had also worked on the improvement of performance coefficient of water cooled air conditioner by employing residential water-cooled air conditioners with a cellulose pad as filling material for cooling tower. They observed that the coefficient of performance of this kind of air conditioner is higher than the conventional air conditioner. Some mathematical work had also been done on a water-cooled air condenser.

Charun et al (2013) [5] have examined the two refrigerants R134a and R404a in long serpentine coils. After thorough investigation he concluded that the condensation process in long coil pipes is different from that in horizontal pipes. Using this he coined a new expression for calculating the average heat transfer coefficient and flow resistance in the two-phase area which could be used for designing water cooled serpentine coil condensers.

And Xu et al (2016) [6] simulated the difference in temperature distribution between shell tube and plate fin heat exchanger, after experiments were performed on the two it was found that shell tube heat exchanger achieved better heat transfer power, especially with large input. This concludes that the major work had been done for the improvement of performance coefficient by applying several methods on water-cooled condensers. Some of the ways had also innovated to deal with the algae formation. And the mathematical work had also been done for calculating the heat transfer coefficient and flow resistance

Singh et al (2016) [7] have compared the performance coefficient between air-cooled and water-cooled but with the help of using evaporative pad in vapour absorption and compression refrigeration system. Evaporative pads are made up of cellulose that improves the coefficient of performance of the system by reducing the condensing temperature to a great extent. The refrigerating effect of water-cooled condenser using evaporative pads exceeds by 2.9-14.4% and coefficient of performance is improved by 1.5-10.2% when compared with an evaporative condenser.

Maheshwari et al (2004) [8] have conducted an experiment in one of the major hospitals in Kuwait to investigate the performance of water cooled and air cooled systems in terms of peak power and energy consumptions.

Hosoz et al (2004) [9] have compared all the three condensers and found that the water cooled system had a greater refrigeration capacity by 14.4% and greater coefficient of performance by 10.2% as compared to evaporative condensers. On the other hand, the refrigeration capacity and performance coefficient of the refrigeration system with evaporative condenser were higher than the system with air-cooled condenser by 31.0% and 14.3% respectively.

Harby et al (2016) [10] have worked on evaporative condensers in residential cooling systems. He focused on energy consumption and its related complications by comparing different types of condensers. This concludes that the different authors have compared all three condensers on various aspects such as performance coefficient, energy consumption, refrigeration capacity peak power, etc.

Chang et. al. [11] Both COP and cooling capacity of the system with the micro channel condenser were higher than those for the round tube condenser in all test conditions. The refrigerant charge amount and the refrigerant pressure drop were measured; the results showed a reduction of charge and pressure drop in the micro channel condenser. A numerical model simulated the micro channel condenser with consideration given to the non-uniform air distribution at the face of the condenser and refrigerant distribution in the headers. The results showed that the effect of the air and refrigerant distribution was not a significant parameter in predicting the capacity of the micro channel condenser experimentally examined.

Liang et. al. [12] This paper describes and analyzes a novel design of multiple parallel-pass (MPP) micro channel tube condenser and its applications to automotive A/C systems. A flow distributor concept is introduced in MPP condenser in order to enable parallel flow arrangement in adjacent flow paths. Throughout analysis of two-phase flow and heat transfer processes in MPP condenser, a two-phase zone enlargement technique is developed to enhance condensation heat transfer and reduce pressure drop. Performance test results show MPP condenser is able to improve heat transfer rate as high as 9.5% while its refrigerant mass flow increases 13.34% when comparing to a benchmark PF condenser.

Pega et. al. [13] This paper presents experimental results from a prototype ammonia chiller with an air-cooled Condenser and a plate evaporator. The main objectives were charge reduction and compactness of the system. The charge is reduced to 20 g/kW (2.5 oz/Ton). Two aluminum condensers were evaluated in the chiller: one with a parallel tube arrangement between headers and ‘‘micro channel’’ tubes (hydraulic diameter Dh ¼ 0.7 mm), and the other with a single serpentine ‘‘macro channel’’ tube (Dh ¼ 4.06 mm). The performances of the chiller and condensers are compared based on various criteria to other available ammonia chillers.

Xueqing et. al. [14] This paper presents an experimental investigation of three liquid vapor separation condensers (LSC) were tested to evaluate their ability to automatically separate the liquid and vapor during condensation. The performance of the LSC system having the greatest cooling capacity and energy efficiency ratio (EER) was then compared with that of the system having a baseline fin-and-tube condenser for various ambient temperatures. The results showed that both the cooling capacity and EER of the two systems were almost the same, with the LSC having just 67% of the heat transfer area of the baseline condenser. In addition, the LSC system was charged with only 80% of the refrigerant in the baseline system.

Lee et. al. [15] The objective of this study is to present test results of a fin and tube condenser was performed using two different configurations of condenser paths (U and Z type) and two kinds of refrigerants (R-22 and R-407C) as working fluids. An integral test facility was constructed to evaluate the heat transfer capacity of the air and refrigerant sides of the condenser. Different condenser capacities were obtained from both the experimental and numerical results, depending on the paths and refrigerants used. R-22 performed better than R-407C for the Z-type path configuration, but no significant difference was found between results using either refrigerant in the U-type path configuration. On average, the numerical results obtained with R-22 were 10.1% greater than experiment data; using R-407C, results were 10.7% less than experiment data. The numerical code can be used as a design tool to develop better condenser paths.

Ribeiro et. al. [16] In this paper the thermal-hydraulic performance of micro channel condensers with open-cell metal foams to enhance the air-side heat transfer is investigated. Three different copper metal foam structures with distinct pore densities (10 and 20 PPI) and porosities (0.893 and 0.947) were tested. A conventional condenser surface, with copper plain fins, was also tested for performance comparison purposes. The experiments were performed at a condensing temperature of 45 C. The air-side flow rate ranged from 1.4 X 10 X 3 to 3.3 X 10 X 3 m3/s (giving face velocities in the range of 2.1e4.9 m/s). The heat transfer rate, the overall thermal conductance, power were calculated as part of the analysis.

Ebrahim et. al. [17] This paper focuses on an investigation of reduction of energy consumption is a major concern in the vapor compression refrigeration cycle especially in the area with very hot weather conditions (about 50 C), where window-air-conditioners are usually used to cool homes. In this article, a new design with high commercialization potential for incorporating of evaporative cooling in the condenser of window-airconditioner is introduced and experimentally investigated. A real air conditioner is used to test the innovation by putting two cooling pads in both sides of the air conditioner and injecting water on them in order to cool down the air before it passing over the condenser. The experimental results show that thermodynamic characteristics of new system are considerably improved and power consumption decreases by about

16% and the coefficient of performance increases by about 55%.

3. CONCLUSION

The performance of condensers was evaluated by various scholars using experimental techniques. The refrigerants investigated are R-22, R407, R134a and R404a. The research findings have shown that water cooled refrigeration system has higher coefficient of performance as compared to evaporative condenser.

The performance of different condensers are also presented on the basis of performance coefficient, energy consumption, refrigeration capacity peak power, etc.

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