A Review paper on Optimal selection of Refrigerant & Condenser Material

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ABSTRACT

Today, refrigeration systems has emerged as an important necessity of industries, as well as society. Refrigeration systems has find wide applications, and so therefore, it becomes necessary to focus on the performance of these systems. Performance of refrigeration systems depend upon heat rejected at high temperatures, which is accomplished by condensers. In condensers, latent heat of the refrigerant is removed. In present research work, performance of condenser for a domestic refrigerator is targeted by using different condenser materials, and also by using different refrigerants, and heat flux and thermal gradient values are proposed for different combinations using ANSYS. The proposed materials are copper, aluminum, and aluminum 6061 alloy, and targeted refrigerants are R022, R404, R502a, and R134a, applied load is of thermal type, by considering surface temperature 313k, and bulk temperature 303k.

Keywords*— Domestic refrigerator, condenser, refrigerant, heat flux, temperature gradient, ANSYS.*

INTRODUCTION

The vapor refrigeration systems now days are universally used for all purpose refrigeration. These systems are being used for the last 100 years but with the development in design of compressors and an increase in their speed have increased its economy from the last few decades only. It is generally used for all industrial purposed from a small domestic unit of 0.5 ton capacity to an air-conditioning plant of cinema hall of 200 tons capacity.

Condensers are considered as the back bone of any refrigeration system. It helps in heat rejection from refrigerant to the universal sink, i.e., atmosphere. In condenser refrigerant loses its latent heat. At entry of condenser vapors coming out from compressor enters, during length of the condenser vapors get converted into liquid form, due to which at the exit of condenser, refrigerant is obtained in the form of saturated or even sub cooled liquid form.

Refrigerants may be considered as blood of any refrigeration system. It flows in all the portions of the circuit, and is responsible for the transfer of heat from lower level to upper level. In evaporator heat carried by products, occupants, and other items, is absorbed by the refrigerant due to which it gets evaporated at very low temperature. These evaporated vapors enter the compressor. Compressor increases pressure, and in turn temperature of the vapors by transferring the vapors from lower temperature to higher temperature. From exit of the compressor, high pressure superheated or saturated vapors enter the condenser where latent heat carried by them is removed by its transfer to a cooling medium (air, water, or any other medium). As a result, refrigerant in the form of saturated or sub cooled liquid is obtained at the exit of the condenser. From exit of the condenser, vapors enter in a throttling device (preferably, a capillary tube or any other device), due to which its state gets converted, and low pressure wet refrigerant is obtained at the entry of evaporator, and in this manner the cycle repeats itself again and again.

In present research work, comparison of different refrigerants and different condenser materials of a condenser of standard length is targeted by comparing heat flux, and thermal gradient. The materials for condenser are copper, aluminum, and aluminum 6061, and the refrigerants used are HCFC, R-40, HFC134a, and HFC152a. For this purpose, approach of modeling and simulation of the system is carried out in ANSYS simulation software.

LITERATURE REVIEW

Kalambe (2015, p. v) The research work aims at modeling of a two-phase flow for different refrigerants for the purpose of predicting the pressure drop and pumping power. In the research work, CFD analysis of a two-phase flow system consisting refrigerants inside a horizontal condenser is carried out using a homogenous model under adiabatic conditions. The targeted refrigerants for this purpose are R134a, R407C, and R1234yf. The analysis is performed considering saturation temperature for the purpose of investigating the local pressure drop due to friction. With the help of homogeneous model, average values of properties are investigated for targeted refrigerants. In next stage, pressure drop data obtained is compared with experimental values, and the separated flow models suggested by the literature. Inner diameter of the condenser is taken as 0.0085 m, and length is 1.2 m.

Raiyani *et al.* (2012) The research work is based on real refrigeration system, and presents the simulation results for commonly used hot-wall condensers of domestic refrigerators. In this research work, researchers tell that geometrical parameters affect the performance of a condenser. In the research work, contact between tube and plate is targeted, and analysis is made by changing point contact with line contact. In the research work, CFD of the targeted system is performed with the help of ANSYS 14 for existing configuration, and results of temperature profiles are validated experimentally. In the next step, contact angle between tube and the plate, using same boundary conditions, is increased, and results are analyzed. In the last step of research, comparison of existing configuration and altered configuration is made on the basis of temperature distribution, heat flux, and thermal gradient. Results of the research work show that with the increase in contact angle, increased values of heat flux and thermal gradient are obtained.

Rebora & Tagliafico (1997) The sensitivityanalysis of the design parameters affecting the performancewas developed for fixed working temperatures withreference to the thickness of the metallic plates, the thicknessof the insulating foam, the evaporator and condenser tubediameters and pitches, and the thermal contact resistancebetween the tubes and the plates.

Bansal and Chin (2002) The research work addresses the comparison between experimental and modeling results yielded by domestic refrigerators using R-134a refrigerant. Experimentation was done on a real domestic refrigerator using R-134a, and values of condenser capacity, pressure loss, and degree of sub-cooling was investigated at different conditions. In the similar manner modeling and simulation of the device was carried out using FORTRON language.

Chandrashekhar M. Bagade et al (2012) Day by day there is increasing demand of refrigerating effect which increases the load on compressor. But sub cooling and superheating are the process used for getting maximum refrigerating effect, ultimately improve COP of the refrigerating system. Condenser plays an important role in any refrigeration system .it is use to remove heat from refrigerant vapour coming from compressor p-h and T-s diagrams clearly shows, the effect of sub cooling after condensate formation on COP. Now a day we are interested in improving COP of refrigeration system, without affecting compressor work. Sub cooling is one of the factors that can improve the COP of refrigeration system. Sub cooling is done in the condenser, thus condenser design is the key factor to improve the COP of domestic refrigerator.

P. Sarat Babu et al (2013) The condenser design plays a very important role in the performance of a vapour compression refrigeration system. Optimized design is possible through theoretical calculations, however may fail due to the reason that the uncertainties in the formulation of heat transfer from the refrigerant inside the condenser tubes to the ambient air. Hence experimental investigations are the best in terms of optimization of certain design parameters. In my experimental work, it is proposed to optimize condenser length for domestic refrigerator of 165 litres capacity. It may give a chance to find a different length other than existing length will give better performance and concluded that the optimum length of coil is 7.01m.

In the present work, the length of the condenser is optimized for a vapour compression refrigeration system used for a domestic refrigeration of 165 Litres capacities, through experimental investigation. Theoretical computation are also made and compared and found that the optimum length of coil is 7.01 m instead of standard value 6.1m.

P. Saji Raveendran et al (2013) In view of Kyoto protocol, there is a pressing need to reduce the energy consumption and environmental impacts of domestic appliances. In the total energy consumption of household appliances, domestic refrigerator plays a vital role. Alternate refrigerants and improvement in the performance of the components can contribute to tackle the above issue in a domestic refrigeration system. In this paper, the performance of a domestic refrigeration system with brazed plate heat exchanger as condenser, and working with refrigerants such as R290/R600a and R134a was studied using experimental method. The result showed that the system with water-cooled brazed plate heat exchanger reduces the per day energy consumption of a system from 21% to 27% and increases the COP from 52% to 68%, when compared to conventional system. The compressor discharge temperature and dome temperature are also dampened. For R134a and R290/R600a, the TEWI of the system with water-cooled brazed plate heat exchanger is lower than that of the system with air-cooled condenser by 26.8% and 21%, respectively. Among the refrigerants, R290/R600a showed higher performance than R134a.

Sreejith K (2014) The objective of this paper was to investigate experimentally the effect of different types of compressor oil in a domestic refrigerator having water cooled condenser. The experiment was done using HFC134a as the refrigerant , Polyol-ester oil (POE) oil which is used as the conventional lubricant in the domestic refrigerator and SUNISO 3GS mineral oil as the lubricant alternatively. The performance of the domestic refrigerator and HFC134a/POE oil system was compared with HFC134a/SUNISO 3GS mineral oil system for different load conditions. The result indicates that the refrigerator performance had improved when HFC134a/SUNISO 3GS mineral oil system was used instead of HFC134a/POE oil system on all load conditions. The HFC134a/SUNISO 3GS mineral oil works normally and safely in the refrigerator. HFC134a/SUNISO 3GS mineral oil system reduced the energy consumption when compared with the HFC134a/POE oil system between 8% and 11% for various load conditions. There was also an enhancement in coefficient of performance (COP) when SUNISO 3GS mineral oil was used instead of POE oil as the lubricant. The water cooled heat exchanger was designed and the system was modified by retrofitting it, instead of the conventional air-cooled condenser by making a bypass line and thus the system can be utilized as a waste heat recovery unit. The hot water obtained can be utilized for household applications like cleaning, dish washing, laundry, bathing etc. Experimental result shows that about 200 litres of hot water at a temperature of about 58ºC over a day can be generated and thus the system signifies the economic importance from the energy saving point of view.

Akshay Gurav et al (2014) Refrigerator has become an essential commodity rather than luxury item. It is one of the home appliance utilizing vapour compression cycle in it process. Performance of this system becomes main issue and many researches are still ongoing to evaluate and improve efficiency of the system. This paper presents effect of evaporative condenser on COP of domestic refrigerator. The purpose of this article is to compare the COP of refrigerator by using air cooled condenser and evaporative condenser of same length and same diameter. This experiment is carried out on domestic refrigerator (150 liter) test rig. In this study, an innovative, evaporative condenser for residential refrigerator was introduced. A vapor compression cycle incorporating the proposed evaporative condenser was tested to evaluate the cycle performance. To allow for evaporative cooling, sheets of cloth were wrapped around condenser to suck the water sprayed on it. The thermal properties at the different points of the refrigeration cycle were measured for typical operating conditions.

P.Saji et al (2014) Residential buildings contribute to the greenhouse gas emissions through the use of energy-intensive products. Household energy consumption and associated emissions can be reduced partly if energy-saving methods are adopted by the occupants. This paper studies the performance of domestic refrigeration system with water-cooled condenser in which the water used for general purposes in a residential building has been considered as the cooling water for the condenser. The circulation quantity of water per day has been varied, and the variation of COP has been studied and presented. The results obtained from the theoretical and experimental studies show that the COP of the system with brazed plate heat exchanger (BPHE) as water-cooled condenser is 57% to 75% higher than that of air-cooled condenser. Moreover, the system with water-cooled BPHE reduces the per day energy consumption of the system from 21% to 27%. The TEWI of the system with water-cooled BPHE is also 5% to 43% lower than that of the system with air-cooled condenser, and thus the building energy-efficiency could be improved by integrating the refrigerator with the general water supply of a residential building.

IDENTIFIED GAPS IN THE LITERATURE AND OBJECTIVES OF THE RESEARCH

On the basis of analysis of theoretical considerations, and research contributions made by different researchers, following gaps in the research are being identified.

1) There is almost nil research available which compares different materials for condensers; and
2) There is almost nil research available which compares different refrigerants.

On the basis of above mentioned gaps objectives of the research work are formulated, as follows:

1) Modeling of a condenser;

2) Simulation of condenser for different materials, and
3) Simulation of condenser for different refrigerants.

METHODOLOGY:

In the present research work, k-ε model is proposed for the solution of the research problem, and the proposed analysis software is ANSYS 15.0, the details of which are presented as follows:

3.1 k- ε Model

K-epsilon (k-ε) turbulence model is a very famous model used in the field of computational fluid dynamics for simulating mean flow characteristics for turbulent flow conditions. It is a two equation type of model which offers a general description of existing turbulence by means of two transport equations. Following are the details of variables obtained through k-ε model:

1. The first transported variable is called turbulent kinetic energy (k), which determines the energy in the turbulence; and
2. The second transported variable is used for determining the rate of dissipation of kinetic energy. This variable is called turbulent dissipation (ε).

Details of the model are as follows (Mierka *et al.*,2006):

In the framework of eddy viscosity models, the hydrodynamic behaviour of a turbulent incompressible fluid is governed by the RANS equations for the velocity u and pressure p.

$$\frac{\partial u}{\partial t} + u\,.\nabla\mathrm{u} = -\nabla\mathrm{p} + \nabla.\left((\mathrm{V} + \mathrm{V_T})[\nabla\mathrm{u} + \nabla\mathrm{u}^{\mathrm{T}}]\right), \qquad \nabla.\mathrm{u} = 0 \tag{3.1}$$

where ν depends only on the physical properties of the fluid, while V_T is the turbulent eddy viscosity which is supposed to emulate the effect of unresolved velocity fluctuations u′.
If the standard k − ε model is employed, then

$$V_T = C_\mu \frac{k^2}{\varepsilon} \tag{3.2}$$

where k is the turbulent kinetic energy and ε is the dissipation rate. Hence, the above system is to be complemented by two additional convection-diffusion-reaction equations for computation of k and ε.

$$\frac{\partial k}{\partial t} + \nabla.\left(ku - \frac{V_T}{\sigma_k}\right) = P_k - \varepsilon \tag{3.3}$$

$$\frac{\partial_\varepsilon}{\partial_t} + \nabla.\left(\varepsilon u - \frac{V_T}{\sigma_\varepsilon}\nabla\varepsilon\right) = \frac{\varepsilon}{k}(C_1 P_K - C_2\,\varepsilon) \tag{3.4}$$

where

$$P_k = \frac{V_T}{2}\,|\nabla u + \nabla u^T|^2 \tag{3.5}$$

and ε are responsible for production and dissipation of turbulent kinetic energy, respectively. The default values of the involved empirical constants are as follows: Cμ = 0.09, C_1 = 1.44, C_2 = 1.92, σ_k = 1.0, σ" = 1.3. ANSYS is considered as one of the renounced tools in the field of simulation, developed by ANSYS Inc., USA. It can be used successfully for the purpose of simulating problems of thermal analysis, structural analysis, computational fluid dynamics, harmonic analysis, modal analysis, transient dynamics, buckling, and other categories. In addition to this, software also offers the facility to develop simple models. With the help of inbuilt library, one can find out the properties of materials, and even add the desired properties or new materials with the known values of properties. ANSYS also include a set of models to solve complex problems of engineering, architecture, physical sciences, mathematical models and other applications. Following are the salient features of the software:

- Offers excellent simulation facility;
- Easy modules for different types of complex analysis like modal, transient, etc;
- Offers different theoreticalperspective to solve a problem with different inbuilt models;
- Simple parts can be easily created;
- Inbuilt library to offer material properties; and
- Better graphics facilities.

MODEL FORMULATION

First step in the research work is the formulation of model of condenser for a refrigeration system. For this purpose dimensions of a standard coil condenser are proposed. Following are the details of dimensions.

Dimensions of Condenser

S.No	Dimension	Value
1.	Length	9.14 m
2.	Outer diameter	9.52 mm
3.	Inner diameter	8.91 mm
4.	Number of turns	06

Solution of the Model

After formulation of model, its solution shall be derived. For this purpose, first of all meshing of the model shall be carried out. With the help of meshing, a body can be made deformable due to which, it can show changes in its properties, dimensions, stress levels, etc. In next step values of heat flux and thermal gradient for different combinations of materials and refrigerants shall be calculated.

CONCLUSION

Present research work is devoted to selection of improved condenser material and refrigerant for a vapor compression refrigeration system. In the research work, *three* different materials for condensers, namely, aluminum, aluminum 6061 alloy, and copper are considered. At the same time, *four* different types of refrigerants namely, HCFC, R404, R152, and R134a are also targeted for *two* parameters namely, thermal gradient, and heat flux. Following results shall be obtained as the result of research:

1) Condenser material offering maximum heat flux;
2) Condenser material offering maximum thermal gradient;
3) Refrigerant showing maximum heat flux; and
4) Refrigerant showing maximum thermal gradient.

As a result of above analysis, after considering the factors of toxicity, and environmental hazards, most suitable condenser material along with the refrigerant, shall be obtained.

REFERENCES

5. Bansal P.K., & Chin T.C. (2002). Design and modeling of hot-wall condensers in domestic refrigerators, Applied Thermal Engineering 22 (2002) 1601–1617.
6. Diwan P & Sahul L (2016). Design and thermal analysis of shell and tube type condenser. International Journal of Innovative Research in Technology, Science & Engineering, 2 (4), 12-22.
7. Gupta Ram Mohan, Singh Shatyendra and Srivastava Simant (2013). Performance Analysis and Calculation of Different Parameters of Condenser Using ANSYS Fluent Software. International Journal of Application or Innovation in Engineering & Management, 2 (7), 529 -534.
8. Kalambe A. R. (2015). Two Phase Flow CFD Analysis of Refrigerants in a Condenser Pipe for Prediction of Pressure Drop and Pumping Power. Master's Thesis, University of Texas.
9. Mallikarjun & Malipatil Anandkumar S (2014). CFD Analysis of Air Cooled Condenser by Using

Copper Tubes and Aluminum Fins. International Journal for Research in Applied Science & Engineering Technology, 2 (10), 214-226.]

10. Mierka, O., Kuzmin, D., & Turek, S. (2006). *Finite element simulation of turbulent bubbly flows*. Univ..

11. Nadadari Bheemesh & Venkateswarlu N.(2015). Design and Heat Transfer Analysis of AC Condenser for Different Materials,2 (8), 461-467.

12. Raiyani1 Akash D., Sheth N. R., and Mehta Niraj C. (2014). Thermal Analysis of Hot Wall Condenser forDomestic Refrigerator. International Journal of Science and Research, 2 (7), 622-626.

13. Rebora Alessandro, Tagliafico Luca A. (1997). Thermal performance analysis for hot-wall condenser and evaporator configurations in refrigeration appliances, Elsevier Science Ltd, (97)77-7.