A Review on Methods of Improving Heat Transfer in Air Cooled Condenser

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Abstract— In systems involving heat transfer, a condenser is a device or unit used to condense a substance from its gaseous to its liquid state, typically by cooling it. In so doing, the latent heat is given up by the substance, and will transfer to the condenser coolant. The primary component of a condenser is typically the condenser coil, through which the refrigerant flows and fins are provided for better transfer and rejection of heat. In this work heat transfer by convection in air cooled condensers is studied and improved along with study of heat distribution over fins. The assessment has been carried out on an air-cooled finned-tube condenser of a vapour compression cycle for air conditioning system. The purpose of the analysis is to investigate the potential benefit of fin distribution on the heat flux and thermal gradient for the same length without failing the load conditions. This paper reviews the different methods researched for improving the heat transfer through fins.

Key words: Fin Density, Heat Transfer, Air Cooled Condenser

I. Introduction

Condensers have been widely used in the fields of refrigeration, air conditioning, water cooler, space heating, automobile and chemical engineering. A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increase convection. Adding a fin to an object increases the surface area and can sometimes be an economical solution to heat transfer problems. Fin-tube heat exchanger with two rows of round tubes is widely used in air-conditioning and refrigeration systems. The reduction in the size and cost of fins is achieved by the enhancement of the heat transfer carried out by the fins. The enhancement of heat transfer from fins has become an important factor that has captured the interest of many researchers. Various techniques and large number of works had been carried out in the aspect of fin material and fin shapes. Also, the optimization process has been carried out under the effect of variable convection heat transfer coefficient. With the development of design of heat exchanger and making some changes without affecting the cost.

II. Literature review

Improving the Heat Transfer Rate for Ac Condenser by Material and Parametric Design Optimization by V Srividhya, G Venkateswara Rao. In this paper authors have designed an air-cooled Condenser for an air conditioner. The material used for coils is Copper and the material used for Fins is Copper or aluminium G Al Cu 4I MG 204 whose thermal conductivity is 110-150W/m K. To reduce the cost of condenser, they are optimizing the design parameters by changing the thickness of the fin for the same length without failing the load conditions. To validate the temperatures and other thermal quantities like flux and gradient, thermal analysis is done on the condenser by applying copper for coil and Fin materials G Al Cu 4IMG 204, Aluminium Alloy Al 1100 and Magnesium alloy. Thermal analysis is done in Cosmos works. The best material and best fluid for the condenser of our design can be checked by comparing the results. Optimization is done by varying the thickness of fin. Analysis is done using fin materials Aluminium Alloy 204, Aluminium Alloy 1100. By observing the thermal analysis results, by using fin material Aluminium alloy Al99, thermal flux is more than Al 204. Results show that Al 1100 have better heat transfer than Al 204 at thickness of 1mm.

Design and Heat Transfer Analysis of AC Condenser for Different Materials by Mr. Nadadri Bhimesh & Mr. Vankateshwarlu. Their main objective here is to design, develop and utilize the high-efficient heat transfer of an AC condenser. The assessment is carried out on an air-cooled finned-tube condenser of a vapour compression cycle for air conditioning system. Heat transfer analysis is done on the condenser to evaluate the material and refrigerant. The materials considered for tubes are Copper and Aluminium alloy 1100 and for fins are 1050 and 1100. The refrigerants varied are R12, R 22 and R 134 but we will only consider HCFC i.e. R 22. From above results, it can be clearly understood that the heat transfer rate is more when refrigerant R22 is used since heat flux is more. When compared the results for tube material between Copper and Aluminium, using Copper is better. But the disadvantage of using Copper is its weight. When compared the results for fin material between Aluminium alloy 1100 and 1050, using Aluminium alloy 1050 is better.

	Temperature °C	Total Heat Flux W/mm²	Directional Heat Flux W/mm²
R-12	90.455	3.5823	0.45062
R-22	90.593	3.8558	0.51633
R-134	89.372	0.96862	0.11589

Fig. 1: Heat Flux for Copper Tubes and Fin Al 1100

	Temperature °C	Total Heat Flux W/mm²	Directional Heat Flux W/mm²
R-12	90.482	3.6677	0.46742
R-22	90.622	3.9495	0.53465
R-134	89.375	0.97875	0.11684

Fig. 2: Heat Flux for Copper Tubes and Fin Al 1050

Residential Air Conditioner Finned- Tube Condenser Heat Exchanger Optimization by Susan W. Stewart, Kristinn A. Aspelund, Monifa F. Wright, Emma M. Sadler and Sam V. Shelton. The study is carried out on a domestic air conditioning system working on R-410a. The optimization is carried out on design parameters which are divided into two categories geometric and operation parameters. Geometric design parameters are decided when the condenser is designed and after it is built they cannot be changed, when on the other hand, it is possible to change the controllable operational parameters without much effort after the condenser is built. Both the height and the depth of the condenser are dependent on other parameters. The height is dependent on number of circuits, number of tubes per circuit and the tube vertical spacing. The depth is then dependent on the number of rows and horizontal tube spacing. As per our scope we will be focusing on Geometric parameters i.e. width of condenser, spacing between fins, vertical and horizontal tube spacing, number of rows and diameter of tube.

- A single row condenser has the highest efficiency for fixed cost and unconstrained frontal area.
- Width/Height ratio should be high to minimise number of bends as well as pressure drop.
- The smallest tube studied, 5/16”, gives the best performance.

Design and Analysis of Different Material to increase performance of AC condenser by Raghu Babu and Srikanth. In this thesis a design optimization technique that can be useful in assessing the best configuration of a finned-tube condenser. Heat transfer by convection in air cooled condensers is studied and improved in this work. The assessment has been carried out on an air-cooled finned-tube condenser of a vapour compression cycle for air conditioning system. Heat transfer analysis and CFD analysis is done on the condenser to evaluate the better design and material. The materials considered for tube is copper and for fins are Aluminium alloys 1100, 6063 and Magnesium alloy for different refrigerants HCFC and 404R. 3D modelling is done in Pro/Engineer and analysis is done in Ansys. CFD analysis is done at different velocities. Theoretical calculations are done to determine heat transfer rate.

REFRIGERANTS	MATERIALS	RESULTS		
		Nodal Temperature (K)	Thermal Gradient (K/mm)	Heat flux (W/mm^2)
HCFC	Aluminum 1100	313	5.52101	1.26983
	Aluminum 6063	313	5.82506	1.12424
	Magnesium	313	6.16722	0.986754
404R	Aluminum 1100	313	6.43696	1.4805
	Aluminum 6063	313	6.07077	1.28162
	Magnesium	313	6.94673	1.11148

Fig. 3: Thermal Gradient and Heat Flux Results

In the above table, the nodal temperature, thermal gradient and thermal flux values are presented from thermal analysis results. From the results, thermal flux is more when Aluminium alloy 1100 is used for fin and refrigerant used is R 404. That is the heat transfer rate is more. Thermal gradient is also more that is the change in temperature over a distance is more.

CFD analysis of Air Cooled Condenser by Using Copper Tubes and Aluminium Fins by Mallikarjun and Anandkumar. In this work heat transfer by convection in air cooled condensers is studied and improved. The assessment has been carried out on an air-cooled finned-tube condenser of a vapour compression cycle for air conditioning system. Heat transfer analysis and CFD analysis is done on the condenser to evaluate the better design and material. The materials considered for tube is copper and for fins are Aluminium alloys 1100, 6063 and Magnesium alloy for different refrigerants HCFC and 404R. CFD analysis is done at different velocities. Theoretical calculations are done to determine heat transfer rate.

From study it has been found that, Thermal flux is more when Aluminium alloy 1100 is used for fin and refrigerant used is 404R. That is the heat transfer rate is more. Thermal gradient is also more that is the change in temperature over a distance is more. It is also found that velocity of air also affects the cooling rate significantly. Increasing inlet velocity from 2.5m/s to 5m/s, yields no advantage but by increasing to 7.5m/s yields better results.

Plate-fin and Tube Heat Exchangers Refrigerant Circuiting Optimization in Vapor Compression Refrigeration Systems by Luis Carlos, Jose Alberto, Samuel Fortunato and Elizabeth de Carmen. Refrigerant circuitry in condensers and evaporators has a significant effect in the performance of refrigeration systems. The optimized project of the refrigerant circuits in refrigeration systems with plate-fin heat exchangers is not trivial, due to the complexity of their representation as well as the high number of possible combinations, even when methodologies of intelligent optimization are used. This new methodology proved to be more efficient than traditional methods. The method was applied, in conjunction with a full refrigeration system simulator for the optimization of a high performance commercial air-conditioning unit, considering the use of heat exchangers with tubes of different diameters.

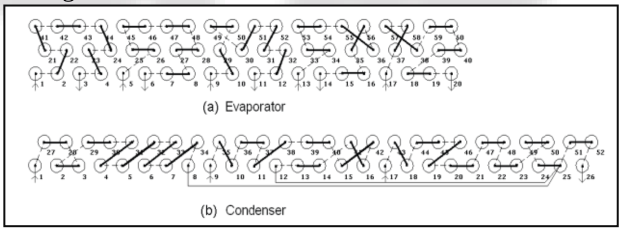
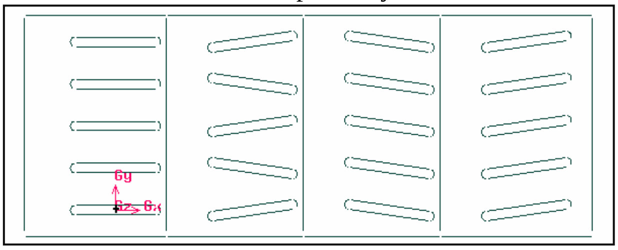


Fig. 4: Optimized Refrigerant Circuitries

COP enhancement between 5.5% and 8.3% for system with R-22, and 6% - 6.5% for R410A, was observed with this optimization method and moreover refrigerant charge was also reduced by 28%. The only drawback is cost and complexity of design.

Performance Enhancement of Air Cooled Condenser by M.M. Awad, H.M. Mostafa, A Elbooz. In order to enhance the performance of air cooled condensers, it is important to take into consideration both of condensation inside condenser tubes and convection outside, where the enhancement in convection side is the dominant one. Aluminium extruded micro-channel flat tubes improve the performance of condensation more than conventional circular tubes but still has potential for air side improving. So, the enhancement of convective heat transfer in air side is achieved in this study by inclination of the flat tubes by a certain angle with respect to horizontal in two cases. The first proposed case is to make convergent and divergent channels for air flow (case 1), while the second case is tilting all tubes in parallel to each other (case 2). A parametric study is performed to investigate the optimum inclination angle (β). Mathematical modelling for air cooled condensers was applied to aluminium flat tubes to study and evaluate these proposed two cases. Theoretical results show that the optimum angle for the proposed two cases is about 4 deg. With corresponding aspect ratio of 0.58. This leads to enhancement of heat transfer coefficient by factor of 1.469 and 1.46 against increase in pressure drop factor of 2.12 and 1.95 for case 1 and case 2 respectively.



Straight Microchannel	Convergent Divergent Tubes CASE 1	Backward Tilted Tube CASE 2	Forward Tilted Tube CASE 2

Using the proposed convergent divergent construction of heat exchanger with optimum angle of 4 degree offers the best enhancement in heat transfer coefficient. The proposed construction of tilting the all tubes in parallel by 4 degrees with respect to horizontal is recommend.

Numerical Prediction of Flow and Heat Transfer in a Parallel Plate Channel with Staggered Fins by K.M. Kelkar and S.V. Patankar. Fluid flow and heat transfer in two-dimensional finned passages were analysed for constant property laminar flow. The passage is formed by two parallel plates to which fins are attached in a staggered fashion. Both the plates are maintained at a constant temperature. Stream wise periodic variation of the cross-sectional area causes the flow and temperature fields to repeat periodically after a certain developing length.

Computations were performed for different values of the Reynolds number, the Prandtl number, geometric parameters, and the fin-conductance parameter. The fins were found to cause the flow to deflect significantly and impinge upon the opposite wall so as to increase the heat transfer significantly. However, the associated increase in pressure drop was an order of magnitude higher than the increase in heat transfer. Streamline patterns and local heat transfer results are presented in addition to the overall results.

Output Results for velocity fields are obtained for three Conditions as following:

- Velocity field for different Reynolds number
- Velocity field for different fin spacing
- Velocity field for different fin height

In all cases, a major portion of the module is occupied by recirculation flow with small secondary recirculation at the base of the fins. It can be seen that the presence of fins causes them to bend and impinge significantly on the top and bottom walls and on the upstream surface of fins. As Re increases, the relative strength and size of the recirculation zone grows causing the through flow to bend more significantly. The effect of decreasing the fin spacing is qualitatively very similar to increasing Re. The effect of increasing fin height is also very similar to that of increasing Re. A substantial increase in heat transfer is observed especially for high Prandtl-number fluids.

Using Porous Fin for Heat Transfer Enhancement by S Kiwan and M.A. Al- Nimr. This work introduces a novel method that enhances the heat transfer from a given surface by using porous fins. In the present work, the thermal performance of porous fins is investigated numerically and a comparison between their performance and that of the solid fins is conducted. The thermal performance of porous fins is estimated and compared with that of the conventional solid fins. It is found that using porous fin of porosity e may enhance the performance of an equal size conventional solid fin and, as a result, save 100 e percent of the fin material. The effect of different design and operating parameters on the porous fin thermal performance is investigated. Examples of these parameters are Ra (Rayleigh) number, Da(Darcy) number, and thermal conductivity ratio. It is found that more enhancements in the porous fin performance may be achieved as Ra increases especially at large Da numbers. Also, it is found that there is an optimum limit for the thermal conductivity ratio beyond which there is no further improvement in the fin performance.

The basic philosophy behind using porous fins is to increase the effective surface area through which heat is convected to the ambient fluid. The total heat transfer carried out by the *N* slides is estimated by multiplying the heat transfer carried out through one slide by *N*. It is clear from this figure that dividing the fin to slides increases the heat transfer dramatically. The same figure shows the material weight which can be saved if the remaining slides have to convect the same amount of heat carried out by the original single fin. As an example, if the original fin is divided to 5 slides, then 30 percent of these slides are sufficient to convect the same amount of heat carried out by the original fin. This implies that we may save 70 percent of the original fin total material.

III. CONCLUSION

If material is considered, large number of works has been conducted to find the best materials for fin. For example, Srividhya and Venkateswara had compared the heat flux generation for three types of aluminium and concluded that Al 1100 must be preferred over Al 204 and Al 99. Extending their work Khadimali and Arunakumari altered the material of both Tubes and Fins. They recorded that Copper tubes proven best with Al 1100 instead of Aluminum tubes, which are lighter and cheaper when compared with copper.

Some of the researchers not only worked on material but also varied the refrigerants in the system likewise a paper by Mallikarjun and Anandkumar includes the comparisons of HCFC and R404 with the former materials i.e. Al 1100, Al 6063 and Magnesium and leaded to the conclusion that Thermal flux is more when Aluminium alloy 1100 is used for fin and refrigerant used is R404 than other combinations. Recently M.A. Al Nimr and Kiwan suggested that thermal performance of fin can be enhanced by using porous fins alternative to conventional solid fins. It increases the initial designing cost but proven to save about 70% of fin material. One of the experimental investigation shows that the creation of turbulence of air on fin by providing vortex generators is also one of the techniques for improving heat transfer suggested by Kumar and Choube. Mostafa and Elbooz presented the case where a new type of tube called Extruded Microchannel Flat Tube made of Aluminium with flat tube profile was used for improving the Heat Transfer Coefficient. The optimization of circuits of flow of refrigerant, using staggered fin structure for reducing the bypass factor and utilization of HTC Porous Carbon foam as a fin material are some other identified methods of improving effectiveness of condenser which are suggested by various researchers.

The reduction in the size and cost of fins is achieved by the enhancement of the heat transfer carried out by the fins. The enhancement of heat transfer from fins has become an important factor that has captured the interest of many researchers. Enhancement of heat transfer from fin can be accomplished through the following techniques:

- Increasing the surface area to volume ratio
- Increasing the thermal conductivity of the fin, and,
- Increasing the convective heat transfer coefficient.

Regarding the first two techniques large number of works had been carried out in the aspect of fin material and fin shapes. Also, the optimization process has been carried out under the effect of variable convection heat transfer coefficient.

IV. Future Scope

A combination of uniform-thickness fins evenly spaced along a round tube is a common use for current condenser configuration because on ease of manufacturing. Unfortunately, more often than not, the air velocity distribution is not uniform and subject to the influence of many factors such as the structure of the duct and the heat exchanger's orientation with respect to the fan. This necessitates the investigation of optimizing fin distribution under non-uniform air distribution. This work could be extended with further improvement by working on following design parameters- Density of Fins (FPI), Distribution of fins, Profile of Fins, Material for Fin.

References

[1] Improving the Heat Transfer Rate for Ac Condenser by Material and Parametric Design Optimization by V Srividhya, G Venkateswara Rao, International Journal of Engineering Research & Technology, Vol 2 issue 1, pp 1-11, January 2013.
[2] Design and Heat Transfer Analysis of AC Condenser for Different Materials by Mr. Nadadri Bhimesh & Mr. Vankateshwarlu, International Journal and Magazine of Engineering Technology, Vol 2 Issue No. 8, pp 461-467, Aug 2015.
[3] Residential Air Conditioner Finned- Tube Condenser Heat Exchanger Optimization by Susan W. Stewart, Kristinn A. Aspelund, Monifa F. Wright, Emma M. Sadler and Sam V. Shelton, South-eastern Region XI Technical Conference, April 6, 2002.
[4] Design and Analysis of Different Material to increase performance of AC condenser by Raghu Babu and Srikanth, International Journal of Research, Vol 3 issue 1, pp 518-547, July 2016.
[5] Plate-fin and Tube Heat Exchangers Refrigerant Circuiting Optimization in Vapor Compression Refrigeration Systems by Luis Carlos, Jose Alberto, Samuel Fortunato and Elizabeth de Carmen, International Refrigeration and Air Conditioning Conference, Paper 1148, 2010.
[6] Performance Enhancement of Air Cooled Condenser by M.M. Awad, H.M. Mostafa, A Elbooz., Acta Polytechnica Hungarica, Vol 4, No. 2, pp 125-142, 2007.
[7] Experimental Study of Heat Transfer Enhancement in Fin Tube Heat Exchanger by Vortex Generator by Dhananjay Kumar and Prof. Alok Choube, International Journal of Engineering Sciences and Research technology, Vol 3(5), pp 186-192, May 2014.
[8] CFD analysis of Air Cooled Condenser by Using Copper Tubes and Aluminum Fins by Mallikarjun and Anandkumar, International Journal for research in Applied Science & Engineering Technology, Vol 2 Issue X, October 2014.
[9] Flow boiling base Heat transfer of R134a based nanofluids in Horizontal Tubes, International Journal of Heat and Mass Transfer, Elsevier, Vol 53, pp 944-951, 2010.
[10] Using Porous Fin for Heat Transfer Enhancement by S Kiwan and M.A. Al- Nimr, Journal of Heat Transfer, Vol 123, pp 790-795, August 2001.
[11] Numerical Prediction of Flow and Heat Transfer in a Parallel Plate Channel with Staggered Fins by K.M. Kelkar and S.V. Patankar, Journal of Heat Transfer, Vol 109, pp 25-30, February 1987.
[12] Enhanced Heat Transfer Using Porous Carbon Foam in Cross Flow for Forced Convection by Yorewearth L Jamin and Abdulmajeed A Mohamad. Journal of Heat Transfer, Vol 129, pp 735-742, June 2007.

