MODELING AND HEAT TRANSFER ANALYSIS OF FINNED TUBE EVAPORATOR USING DIFFERENT MIXED REFRIGERANTS

Namani Sai Teja[1] Mr. Sangamesh B Herakal[2] Dr. N Jeevan Kumar[3]

[1]M.Tech student(CAD/CAM) Department of Mechanical Engineering, Holymary Institute of Technology & Science, Hyderabad.

[2]Assistant Professor Department of Mechanical Engineering, Holymary Institute of Technology & Science, Hyderabad.

[3] Professor and Head of the Department of Mechanical Engineering, Holymary Institute of Technology & Science, Hyderabad.

Abstract

The vapour compression refrigeration system (VCRS) is an energy system used for preservation and cooling of household, agricultural and industrial products but the energy consumption of the system is high globally. The low thermal conductivity of refrigerant can be enhanced by dispersing nanoparticles into the refrigerant. The use of Nano refrigerant or Nano lubricant has been found to be useful in the reduction of energy consumption and enhancement of the VCRS performance. This review discusses the energy and exergy performance of the VCRS with the aim of identifying some critical factors that affects the performance optimization and exergy destruction within the system.
In this thesis, to determine the effect of evaporator load on performance of vapour compression refrigeration system with eco-friendly refrigerants with sub-cooling & compared it with without sub-cooling. The refrigerant used is graphene & the Mixture of Propane (R290) and Isobutene (R600a) alternative refrigerant to Hydro Fluorocarbon (HFC) and Chlorofluorocarbon (CFC) compounds in this analysis. Thermal analysis is to determine the heat flux and temperature distribution at different fin shape geometries(hexagonal, square and circular) at with and without graphene coating finned tube evaporators.
CFD Analysis is to study the performance of the proposed mixture and also compared with HFC refrigerants R12 and R134a with respect to condensing temperature.
Key words: CFD, Thermal, CATIA, Fin, aluminum alloy 7475.

1. INTRODUCTION

An evaporator is a device that is used to transfer a chemical substance from its liquid state to its gaseous state (vapor). The liquid is evaporated, or vaporised, into a gas form of the desired component in this procedure. In a closed compressor-driven liquid coolant circulation system, an evaporator is a sort of radiator coil. This is alluded to as a cooling framework (A/C) or refrigeration framework since it permits a packed cooling compound, for example, R-22 (Freon) or R-410A, to vanish/disintegrate from fluid to gas inside the framework while engrossing warmth from the encased cooled region, like a cooler or indoor rooms.This works in the shut A/C or refrigeration framework with a condenser radiator curl that trades the warmth from the coolant, for instance, into the general climate An alternate sort of evaporator can be utilized to warm and conceivably heat up an item that contains a fluid all together for the fluid to dissipate. Water or different fluids can be eliminated from fluid based blends utilizing the right system. Vanishing is ordinarily used to think fluid food sources like soup or to spread the word about concentrated milk as "dense milk," which is made by dissipating water from milk. The motivation behind vanishing in the fixation cycle is to dissipate most of the water from an answer containing the ideal item.

1.1 Finned Evaporators

Finned evaporators are uncovered cylinder evaporators that have been covered with balances. It is important that there is acceptable contact between the curl and the blades for balances to be viable. Balances are bound straightforwardly to the loop's surface in specific conditions, and blades are just positioned over the outside of cylinders or curls in others. Finned evaporators are found in basically a wide range of forced air systems, including window, split, bundled, and focal cooling. The cooling coi in this framework is a finned evaporator's. The warmed air is cooled by going through a finned evaporator. Inward balances are added to the tubing to work on the productivity of warmth move from the evaporator. These blades are made by delivering fluctuated inward cross area structures while tubing is being produced.

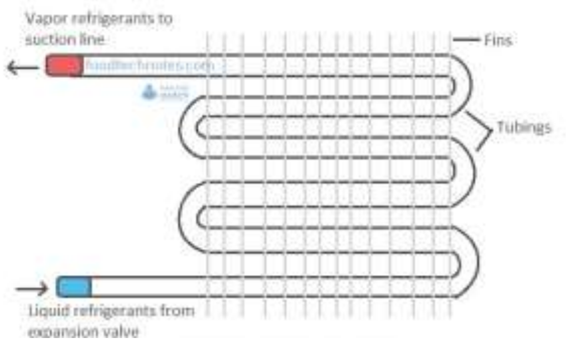


Fig 1: finned tube evaporator

1.2 Refrigerants

R134a Refrigerant is a normal refrigerant that is utilized in an assortment of cooling applications and comes in blue chambers. R134a has little ozone exhaustion potential and has a low nursery impact because of its characteristics as a HFC (hydrofluorocarbon) refrigerant. R134a is a phenomenal substitute for R12, which has been utilized in an assortment of uses.

1.2.1 Properties

Density = 1326.6 kg/m3
Specific heat = 1043.0 j/kg/k
Thermal conductivity = 0.0042 w/m-k
Viscosity = 0.000279 kg/m-s
R-410C is a refrigerant comprised of a combination of hydro fluorocarbons. It's a combination of difluoromethane (R-32), pentafluoroethane (R-125), and 1,1,1,2-tetrafluoroethane with azeotropic properties (R-134a). Difluoromethane is utilized to give heat limit, though pentafluoroethane is utilized to reduce combustibility and tetrafluoroethane is utilized to bring down pressure. Consumed orange is the shade of R-410C chambers.

R22a could be a substitution for R22, perhaps the most predominant hydrocarbon refrigerants available, despite the fact that it should be eliminated because of ozone layer concerns. The EPA, then again, offers a rundown of naturally reasonable options on its site, and it firmly goes against the utilization of R22a.

2. LITERATURE SURVEY

Mota-Babiloni et al. [1] and UNEP [2] HFC refrigerants were listed among the chemicals that contribute to global warming. Consequently, a treaty was signed by the United Nation members to limit the use ofHFCs and phase out HFCs by developed countries in 2020 and completely phase out HFCs in 2030 worldwide. Currently, the use of HFCs in domestic VCRS has been phased out completely in Europe. Since then, an effort has been geared towards the use of natural refrigerants in the refrigeration system. Hydrocarbon refrigerants have been adopted as of the refrigerants and Isobutene (R600a) is one of them. Numerous researchers have made effort to replace and improve the performance of hydrocarbon refrigerant in VCRS
Agrawal et al. [3], Kasaeian et al. [4] and Oyedepo et al. [5] they all concluded that hydrocarbon refrigerants can serve as substitutes to R12 and 134a in vapour compression system. The energy demand associated with refrigeration systems has made researchers think about new technology to enhance the energy efficiency of the refrigeration system Di Battista and Cipollone [6] through the introduction of nanotechnology. The two popular methods of introducing nanoparticles in refrigeration systems: one is by dispersing it in the base refrigerant while the other is by dispersing the nanoparticles in the base lubricant, this result into nanolubricant which eventually mix with the refrigerant in refrigeration system in operation. The application of nanotechnology in refrigeration systems is new and has started gaining attention.

Rasheed et al. [7]. Graphene is capable of reducing friction energy consumption and also have good anti-wear properties when being used either as additives in lubricants Gupta et al. [8] and Mao et al. Zhao et al. [9]. The use of graphene nanoparticles as additives in the lubricant is gaining swift attention from researchers. However, the properties of nanoparticles that affect the performance refrigerant in refrigeration system depend on chemical and physical properties such as nanoparticles size, shape and concentration of the nanoparticles in the base lubricant. Some researchers have reported on the use of nanoparticles as additives in lubricating oil.

2.1 METHODOLOGY

• Go over the review of the literature.
• Using CATIA parametric software, construct a 3D model of the evaporator.
• R134A, R22A, and R410C are among the fluids available.
• Calculate thermal loads using CFD and thermal analysis on the evaporator assembly.

2.2 PROBLEM DESCRIPTION:

This project's goal is to create a 3D model of the evaporator and use finite element analysis to investigate the evaporator's CFD and thermal behaviour. Designing was done with CATIA 3D modelling software, while

CFD and thermal analysis were done with ANSYS analysis software.

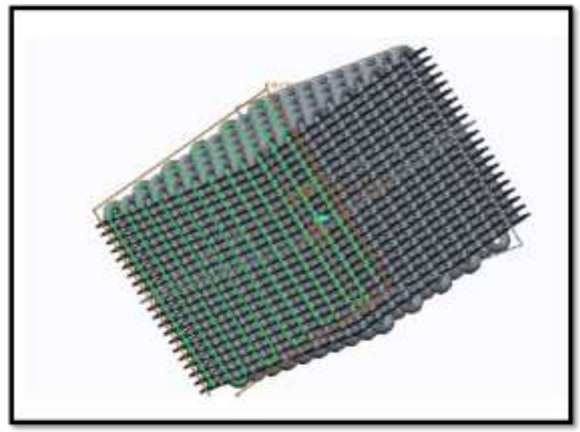
3. Modeling and analysis

The utilization of program to make an item or an article is known as PC supported plan (CAD). The utilization of program and innovation to design, sort out, and control the exercises of an assembling plant is known as PC supported assembling (CAM). PC Aided Engineering (CAE) is the utilization of program to tackle designing issues and look at CAD-made items. PC Aided Three-dimensional Interactive Application (CATIA) is an abbreviation for Computer Aided Three-dimensional Interactive Application. It is a mainstream 3D demonstrating program utilized by organizations in an assortment of enterprises, including aviation, cars, and buyer products. Dassault Systems' CATIA is a multi-stage 3D programming suite that incorporates CAD, CAM, and reproduction.

3.1 ANSYS

ANSYS is a limited component examination (FEA) programming suite that might be utilized for an assortment of utilizations. Limited Element Analysis (FEA) is a mathematical methodology for separating an enormous framework into little (client characterized) parts called components. The product makes a careful clarification of how the framework capacities in general by executing conditions that direct the conduct of different components and settling them by and large.
The impacts of consistent warm loads on a framework or segment are determined utilizing consistent state warm investigations. Prior to playing out a transient warm investigation, clients often play out a consistent state study to help make gauge conditions. A consistent state study can likewise be utilized as the last phase of a transient warm investigation, after all transient impacts have died down. Temperatures, warm slopes, heat stream rates, and warmth transitions in a thing initiated by warm loads that don't shift over the long run can be determined utilizing ANSYS.
Computational liquid elements (CFD) is a part of liquid mechanics that settles and investigations issues including liquid streams utilizing mathematical techniques and calculations. The calculations important to demonstrate the collaboration of fluids and gases with surfaces characterized by limit conditions are performed on PCs. Better arrangements are conceivable with high velocity supercomputers. Momentum research is yielding programming that expands the precision and speed of troublesome reproduction situations like transonic or violent streams. The underlying trial approval of such programming is done in an air stream, with full-scale testing giving a definitive affirmation.

3.2 3d Model of Evaporator



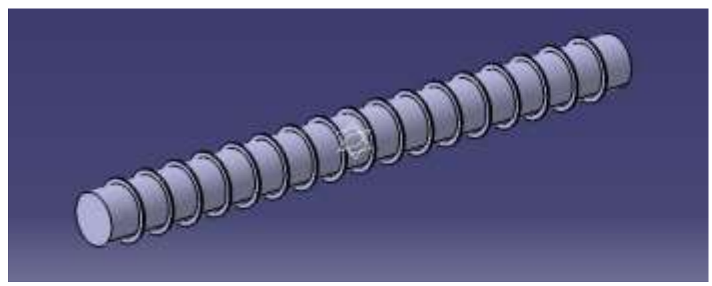


Fig: 2 circular finned tube evaporator

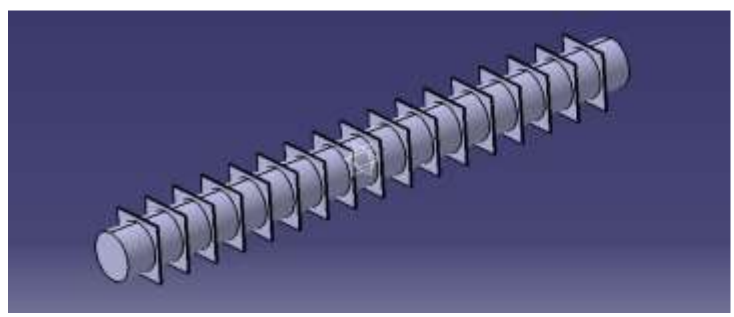


Fig: 3 Rectangular finned tube evaporator

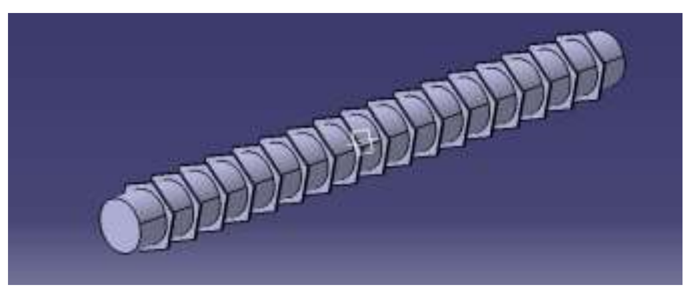


Fig:4 3d Model of hexagonal Finned Tube Evaporator4. RESULTS AND DISCUSSION

4.1 CFD Analysis of Finned Tube Evaporator

Case 1-Circular Fins

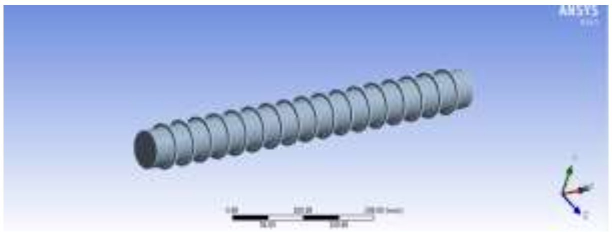


Fig 4: imported model

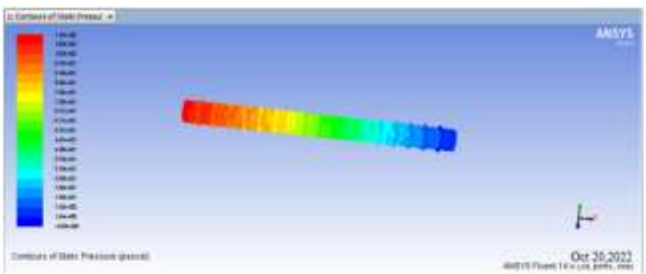


Fig 5: pressure counters

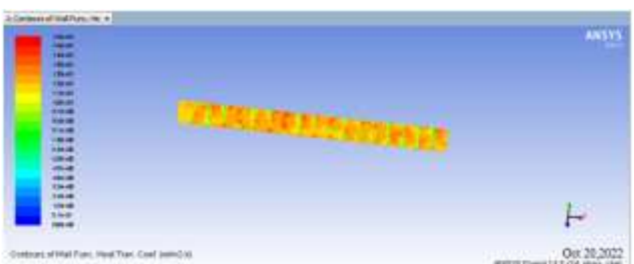


Fig 6: Heat Transfer Coefficient

Mass Flow Rate

Mass Flow Rate	(kg/s)
inlet	1.5000006
interior-partbody	-0.65700382
outlet	-1.4979161
wall-partbody	0
Net	0.0020844936

Case 2-Rectangular Fins

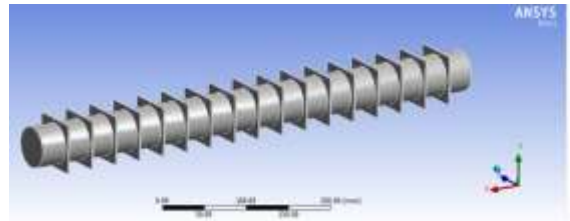


Fig 7: imported model

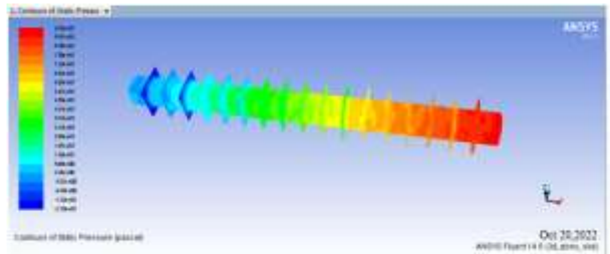


Fig 8: pressure counters

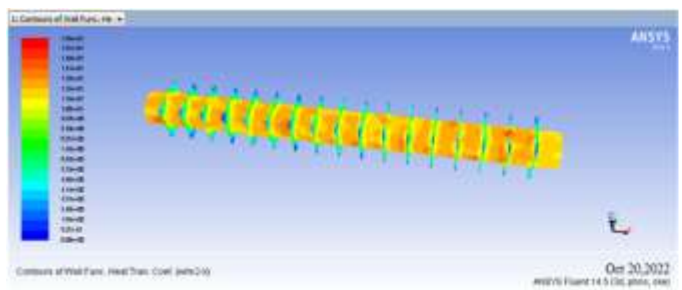


Fig 9: Heat Transfer Coefficient

Mass Flow Rate

Mass Flow Rate	(kg/s)
inlet	1.5000005
interior-partbody	2.9729486
outlet	-1.4968315
wall-partbody	0
Net	0.0031689405

4.2 THERMAL ANALYSIS OF FINNED TUBE EVAPORATOR

Case 1-Circular Fins

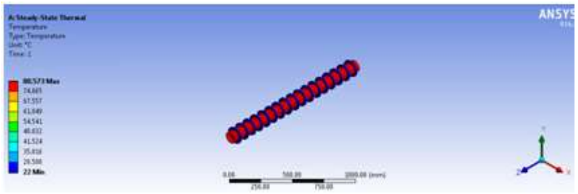


Fig: 10 Temperature

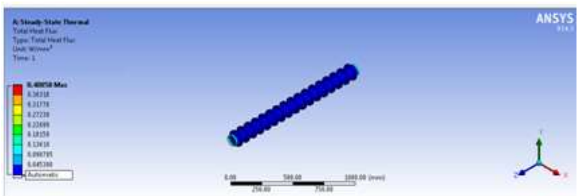


Fig: 11 Heat flux

Case 2-Rectangular Fins

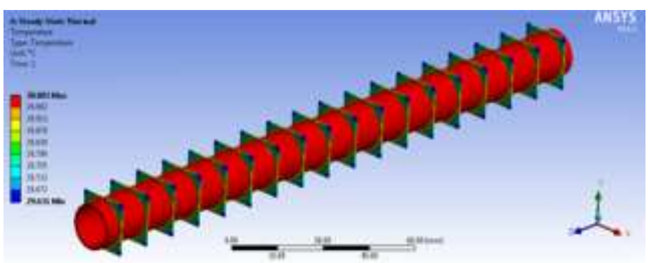


Fig :12 Temperature

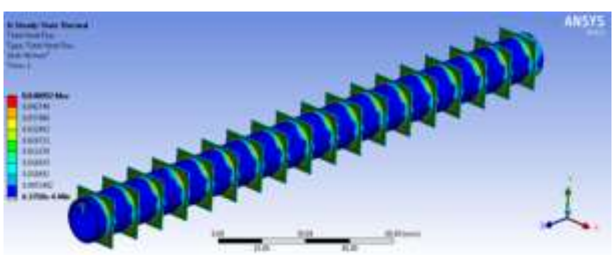


Fig :13 Heat flux

4.3 RESULT TABELS

Table 1: CFD analysis results

Fin geometry	Fluid volume fraction (%)	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (w/mm²- k)	Mass flow rate	Heat transfer rate(w)
Rectangular	Mixed refrigerant	9.56e+01	7.33e-01	1.65e+02	0.003168	127.98
	R12	9.58e+01	7.63e-01	2.56e+01	0.003268	155.50
	R134	9.68e+01	7.96e-01	2.91e+01	0.002834	113.98
Circular	Mixed refrigerant	1.15e+02	7.36e-01	1.62e+01	0.0020844	84.30
	R12	1.20e+02	7.61e-01	2.46e+01	0.0021493	105.52
	R134	1.30e+02	7.99e-01	2.94e+01	0.0022530	90.718
Hexagonal	Mixed refrigerant	1.01e+02	7.30e-01	1.60e+01	0.0021239	85.785
	R12	1.47e+02	7.62e-01	6.63e+01	0.0023427	115.00
	R134	1.53e+02	7.90e-01	8.10e+01	0.0024602	98.972

Table : Thermal analysis results

Fin geometry	Materials	Temperature (°C)	Heat flux (W/mm²)
Rectangular	Aluminum alloy 7475(without graphene coating)	20.803	1.0193
	With graphene coating	14.412	1.9435
Circular	Aluminum alloy 7475(without graphene coating)	5.62	0.98626
	With graphene coating	8.0818	1.531
Hexagonal	Aluminum alloy 7475(without graphene coating)	15.162	0.971
	With graphene coating	2.382	1.676

5. CONCLUSION

In this thesis, to determine the effect of evaporator load on performance of vapour compression refrigeration system with eco-friendly refrigerants with sub-cooling & compared it with without sub-cooling. The refrigerant used is graphene & the Mixture of Propane (R290) and Isobutene (R600a) alternative refrigerant to Hydro Fluorocarbon (HFC) and Chlorofluorocarbon (CFC) compounds in this analysis. Thermal analysis is to determine the heat flux and temperature distribution at different fin shape geometries(hexagonal, square and circular) at with and without graphene coating finned tube evaporators.

CFD Analysis is to study the performance of the proposed mixture and also compared with HFC refrigerants R12 and R134a with respect to condensing temperature.

By observing the CFD analysis results, heat transfer coefficient increases the Mixed refrigerant at rectangular fin , mass flow rate is more for rectangular fin at R12.

By observing the thermal analysis results, the heat flux is more for with graphene coating material at Hexagonal fin than circular and Rectangular fins.

So we can conclude that with graphene coating material is the better material for fin tube evaporator and fluid is mixed refrigerant.

References

[1] Mota-Babiloni A, Makhnatch P, Khodabandeh R. Étudesrécentes sur la substitution des HFC par des frigorigènessynthétiquesalternatifs à faible GWP: performances énergétiques et impacts environnementaux. Int J Refrig 2017;82:288–301. http://dx.doi.org/10. 1016/j.ijrefrig.2017.06.026.

[2] UNEP, UNEP. HandBook for the Montreal Protocol on Substances that Deplete the Ozone Layer. 2012.

[3] Agrawal N, Patil S, Nanda P. Experimental studies of a domestic refrigerator using R290/R600a zeotropic blends. Energy Procedia 2017;109:425–30. http://dx.doi.org/10.1016/j.egypro.2017.03.051.

[4] Kasaeian A, Hosseini SM, Sheikhpour M, Mahian O, Yan WM, Wongwises S. Applications of eco-friendly refrigerants and nanorefrigerants: A review. Renew Sustain Energy Rev 2018;96(July):19–99. http://dx.doi.org/10.1016/j.rser.2018.07.033.

[5] Oyedepo SO, Fagbenle RO, Babarinde T, Tunde A. Effect of capillary tube length and refrigerant charge on the performance of domestic refrigerator with R12 and R600a. Int J AdvThermofluid Res 2016;2(1):2–14.

[6] Di Battista D, Cipollone R. High efficiency air conditioning model based analysis for the automotive sector. Int J Refrig 2016;64:108–22. http://dx.doi.org/10.1016/j.ijrefrig.2015.12.014.

[7] Rasheed AK, Khalid M, Rashmi W, Gupta TCSM, Chan A. Graphene based nanofluids and nanolubricants - Review of recent developments. Renew Sustain Energy Rev 2016;63:346–62. http://dx.doi.org/10.1016/j.rser.2016.04.072.

[8] Gupta B, Kumar N, Titovich KA, Ivanovich KV, Sidashov AV, Dash S. Lubrication properties of chemically aged reduced graphene-oxide additives. Surf Interfaces 2017;7:6–13. http://dx.doi.org/10.1016/j.surfin.2017.02.005.

[9] Zhao J, Mao J, Li Y, He Y, Luo J. Friction-induced nano-structural evolution of graphene as a lubrication additive. Appl Surf Sci 2018;434:21–7. http://dx.doi.org/10.1016/j.apsusc.2017.10.119.

[10] Jia T, Wang R, Xu R. Performance of MoFe2O4-NiFe2O4/Fullerene-added nano-oil applied in the domestic refrigerator compressors. Energy Econ 2014;45:120–7. http://dx.doi.org/10.1016/j.ijrefrig.2014.06.001.

[11] Melnyk AV. A complex investigation of the nanofluids R600 a -mineral oil-AL 2 O 3 and R600 a -mineral oil-TiO 2.Thermophysical properties Uneétudecomplexe des propriétésthermophysiques des nanofluides R600a-huile minérale-Al 2 O 3 et R600a-huile. Int J Refrig 2017;74:488–504. http://dx.doi.org/10.1016/j.ijrefrig.2016.11.008.

