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A Review of Advance Mechanical Thermal Analysis of Fins

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Abstract

The cooling performance of engine and refrigeration and air conditioning is a biggest issue and areas as well electricity consumption. There are trying to work of various researches in this field to improve the effect of fins on performance of heat transfer. Fins are provided on circumference of condenser and other Heat transfer surfaces for maintain temperature and increase efficiency of refrigeration system with less electricity consumption. In this paper has included summarize various researcher that were worked on the fins and refrigeration system. The aim of this review paper is to analysis the effect of refrigerants and fins on the refrigeration system with safe work without effect on global warming and greenhouse effect and electricity consumption by varying refrigerants, geometry of fins, materials, Numbers of fins, length, thickness, width, height, shape, of fins. From this review it is observed that the effect of refrigerant on Refrigeration system through CFD Analysis done and Fins on different components of refrigeration and other heat transfer system through Finite Element analysis done.

Keywords: Refrigerants; Fin Materials; Geometry; Heat dissipation enhancement

How to Cite This Article

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Introduction

Refrigeration system has multiple components such as condenser, compressor, expansion valve and evaporator. Refrigerant flowing through these elements changes its phase and has effect on temperature of surrounding fluid. Heat is rejected to surrounding in condenser. Fins are provided on circumference of condenser surface for maintain temperature and increase efficiency of refrigeration system with less electricity consumption. Refrigeration system is widely used in various applications such as air conditioning, refrigeration and industrial cooling systems. The performance of these systems depends significantly on heat transfer rate which can be enhanced by using fins on heat transfer surfaces. Various geometries, materials and configurations of fins are studied to improve efficiency and reduce energy consumption.

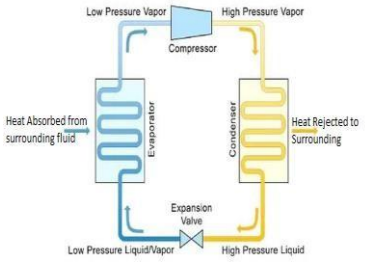


Fig.1. *Refrigeration System*

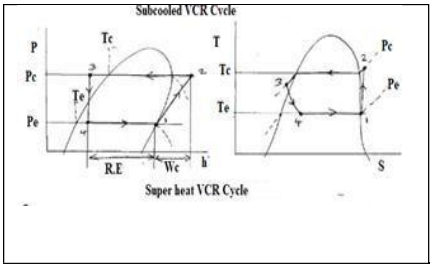


Fig. 2. *P-h and T-S Diagram of vapor compression refrigeration System*

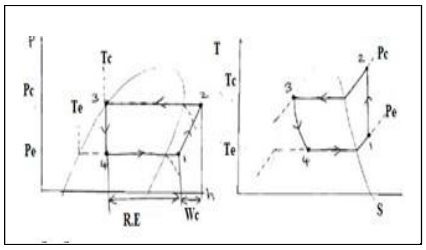


Fig. 3. *P-h and T-S Diagram of vapor compression refrigeration System*

Types of Fins (Extended Surface) and Applications

Straight Fins (Longitudinal)

- Description: Simplest form, extending straight from the surface, often with uniform triangular, rectangular, or circular cross-sections.
- Applications: General-purpose heating/cooling, simple heat sinks, motorcycle engines, basic radiators.

Annular Fins (Circular)

- Description: Ring shaped fins attached to cylindrical bodies (like tubes).
- Applications: Cooling of pipes, engine cylinders, heat exchangers where tubes are present.

Pin Fins (Cylindrical or Conical)

- Description: Individual conical or cylindrical protrusions.
- Applications: High performance heat sinks for electronics, compact devices needing excellent convective cooling.

Corrugated or Wavy Fins

- Description: Fins with wavy or sinusoidal profiles increasing turbulence and heat transfer.
- Applications: Condensers, radiators, air conditioning coils for improved efficiency.

Louvered Fins

- Description: Fins with angled slits (louvers) that induce mixing and break boundary layers.
- Applications: Automotive radiators, compact heat exchangers, air conditioners.

Perforated or Porous Fins

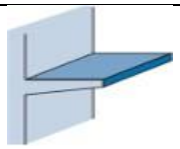
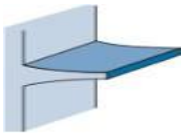
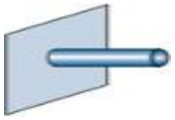
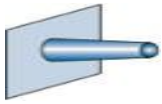
- Description: Fins with holes or porous structures enhancing turbulence and surface area.
- Applications: Heat exchangers, high efficiency cooling systems.

Spiral or Serrated Fins

- Description: Continuous helical or notched fins.

- Applications: Enhancing heat transfer in tubes and industrial processes.
- Automotive: Condensers, intercoolers, engine cooling, Radiators,
- Electronics: Heat sinks for GPUs, LEDs, CPUs, power electronics.
- Industrial: Power plant turbines, compressors, transformers, chemical reactors.
- HVAC: Condensers in air conditioners, Evaporators, refrigerators.

Table 1. *Geometry of Fins*

 a) Longitudinal fin of rectangular profile	 b) Cylindrical tube equipped with fins of rectangular profile
 c)Longitudinal fin of trapezoidal profile	 d) Longitudinal fin of parabolic profile
 e) Radial fin on Cylindrical tube of rectangular profile	 f) Radial fin on Cylindrical tube of trapezoidal profile
 g) Pin fin Cylindrical Spine	 h) Pin fin Truncated conical Spine

Literature Review

1. Pramod Kumar, Jagdish saini, Purushottam Sahu-In this paper Thermal analysis and CFD analysis done on condenser by using ansys software.by variation of refrigerant R134, R11.analysis had done by without fin and with fin on condenser performance. Heat rejected has found more in fin with condenser (0.81 W) as compared without condenser (0.44 W).

2. S.O.Banjo, B.O.Bolaji -VCR analyzed by using Refrigerant LPG with Mixture of Isobutene, Butane and Propane with change of fin spacing and from 2mm to 6 mm .2mm spacing found high COP. Space reduces then COP Increases. Cooling purpose nonofluid used for cooling and high thermal conductivity material could be used between fin spacing.

3. Vemula Nagarjuna, Vasili Srinivas- Copper had used tube and Al for fin. Refrigerent R32 and R134 its properties studied. Heat Transfer rate has found more by using R32 Refrigerant with 0 ozone deflection. Calculation of HEAT flux studied with dimensions and its properties.

4. Yanan Camaraza Medina, Angel M.Rubio -Finned tube bundle in air cooling in condenser with variation of flow rate, diameter, thickness height and number of fins per length has studied. Changes in its efficiency

5. Mr. K. Manikandan, S. Thirumoorthi - Plate, Circular, Plate fins with hole and Draft pin fin.Pin fins with conical Draft has found better for Heat Transfer Compare other.

6. K.M.Arunraja, S.r.Rajabalayana - Heat was generated because of friction and compressed air with high pressure. Heat Flux and Temperature Profile Used Measure Efficiency. Circular, triangle, Trapezoidal and rectangle, Al Material has used for fin.Weight of fin effect Heat Transfer Rate and Efficiency.

7. S.Gowtham, V. Harish Naida - Al, copper, Mg fins and Heat flux has calculated as pr geometry. Heat flow rate of curve fin and rectangle has found 5:6.

8. Dolly Bhasker,Sudhir - Louverded Fin Heat Exchanger type was compared traditional palate heat exchanger. Fin has changed its piths, height, depth and CFD Analysis has carried by variation of different refrigerant and AL material has found used for fin through Ansys.

9. Yang Han,Rong Feng,Taiyang xiao - Total thermal resistant of the fin tube condenser increase by fin spacing increases.

10. Omkar Kurri,Ninad Mal,Parag Jain - R12,R-125,R-134 a , R407c Refrigerant had used for CFD analysis In VCR system.Al,Brass, Copper fins have found. R407c Refrigerant has less flammable and 0 ozone deflection and no global warming and copper has better result found in thermal analysis .

11. Ansari wasi Ahemad,Prajapati Anurag,Rai Sahil Kumar - Refrigerant used R22.Heat Transfer efficiency for condenser has increase by changing tube and fin materials. COP has found more copper fin as compared al fin.

12. Nares Chimres, Jatuporn Kaewon- In this paper has shown 8 Spiral fin by various fin pitches and fin diameter on Heat Transfer and wavy fin. Heat transfer coefficient and pressure drop of wavy fin has found greater than spiral fin.

13. Indresh Singh Goutam, Vishwajeet Kureel- In this paper has shown Domestic refrigerator by varying the fin spacing from 4 mm to 9 mm of the condenser and checked behavior of refrigerant, COP, Compressor time, discharge pressure and energy consumption. COP has found more for less spacing 4mm. Pressure gauges and a temperature sensor for pressure and temperature measurement purposed used and leak detection by soap solution and clean by system by N2 gas.

14. Sushma S, TK.Chandrashekar- In this paper has shown Geometry, Material, Number, and Thickness of fin changed.Materials Al, Brass, M.S. Fin Efficiency of Aluminum Fin material has found greater than Brass and M.S fin length of fin has vary heat flow, efficiency and effectives. Triangular fin has increase heart transfer rate than rectangular fin.

15. Dheya Ghanim Mutasher- In this paper has shown Domestic refrigerator –Refrigerant used-HFC134a. Compressor work reduces with elliptical condenser without fin and power consumption reduces compared conventional condenser. COP Increase by elliptical condenser without fin in VCR System.

16. E.poornanandth and M.Johm Babu.- In this paper has shown a Refrigerant used –Freon or R-22, R32, R60 a Continuous rectangular, interrupted rectangular, continuous circular, interrupted circular, Tapered Fin shape used. CFD Analysis done by different refrigerant parameters Pressure, Velocity, Mass flow rate, heat transfer rate and heat transfer coefficient. Continuous circular has shown better result of heat transfer rate with R32 Refrigerant.

17. Vermula Nagarjuna, Vasili Srinivas- In this paper has shown as a Heat Transfer analysis on AC Condenser by varying materials AL alloy 1060, 6060 and 7050 and refrigerant R32, R134.Copper tube and AL alloy 1060 fin and has shown better for heat transfer rate with optimized R32 Refrigerant.

18. Mohammad Shafiuddin, Ayubashwak, Suresh Vellingiri- In this paper has shown a Flow analysis of condenser fin by different material of fins and varying refrigerants R12, R22, R134, Flow rate, temperature and Velocity of refrigerant by using Ansys CFD .Al alloy 1050 fin has better result and R22 has found more heat transfer rate.

19. Steady state heat conduction done. - In this paper has shown as a Length of fin, speed, height and width and triangle, rectangle, trapezoidal shapes parameters have found effect in efficiency, COP and Temperature dissipation with economy.

20. Xing xue,Xianming Feng,Junmin wang,Fang Liu- In this paper has shown as a Transient analysis done by changed compressor speed, air temperature, air and refrigerant flow rate and predicted condenser performance through control algorithm.

21. Gaural Chaudhary, B.P.Kumbhare -In this paper has shown as an Effect of ammonia, chloroform, pure distilled water as fluids in heat pipe with or without fin. Fin increases contact surface area fluid and exit temperature reduces. Efficiency has more by using chloroform fluid.

22. Yonghua cao, Xiaomin Cui- In this paper has shown as a Effect of Fin Width on Heat transfer tested by vary Speed, heat transfer coefficient. Heat flux increases at low speed. CFD Analysis done by flow rate of refrigerants. Velocity 3.5 m/s, Wall- Temperature-60ºC and Wall- Aluminum.

23. Obaid T.Fadhil, Mustafa B.Al Hadithi ,Harith M.Al Hiti- In this paper has shown as a Fluid as water in finned condenser. Overall Heat transfer coefficient increases with increases heat flux as input. Input power has varied from 2 w to 40 w and tube has shown copper.

24. Akashnil Kayal, Arijit- In this paper has shown as a Fin changes tip, base temperature, fin array, fin efficiency, fin effectiveness. Copper fin has found high effectiveness; efficiency increase because of high thermal conductivity.

25. Cease Maria Joppola, Luca Molinaroli - In this paper Effectiveness has calculated by NTU Method

26. N.Phani Jaja Raoet al- In this paper did transient thermal by vary geometry, material, thickness of cylindrical fin Al Alloy and Magnesium alloy.

27. P.A.Patil, S. N. Sapal- In this paper has shown Micro tube fin and variable material analysis done on air cooled condenser, .R22, R134a, R404a, R507c.Tube copper material and Aluminum Fin. High fin tube ratio is 40.R404 a best refrigerant for thermal analysis. In this research reduces compressor power and fan power.

28. Santiago Martinez Ballester- In this paper Micro channel heat exchanger condenser was working as propane fluid .Gas cooler C02 .Fins cut has effect of heat transfer.

29. Nomit Kumar Sahu , Vinay Kumar and G.Babu and M.Lavakuma- In this paper Thermal and CFD analysis done on Air cooled finned tube by varying different diameter 8 mm to 10mm tubes and refrigerant and turbulence .on that analysis R410 refrigerant has Preferred and 10 mm diameter tube has maximum heat rejected and 8 mm diameter tube has maximum heat rejected . Fin Analysis done by varying geometry, material, thickness, and velocity changes from 0 to 11 m/s. CFD done

30. Mladen Bosnjakovic ,Simon Muhic- In this paper did stainless steel star shaped fin and annular solid fin with hole diameter 2mm to 4 mm. CFD Analysis done for changing flow and diameter of holes, numbers and size effect in thermal performance with less mass of fin and economic optimize production cost.

31. B. Ramesh- In this paper Thermal analysis done on AC Condenser Fins by variable material Al alloy Mg alloy, changing thickness and maximum thermal conductivity and HC (Hydro carbon) and HCFC(Hydro carbon flouro carbon).Al alloy fin has better heat transfer rate.

32. R.Phani Krishana,V.ravi kumar- In this paper Steady state thermal analysis done and CFD Analysis done on air cooled condenser by varying different refrigerants R22, R407C and different fin materials such as copper, AL, Brass with high thermal conductivity and variable thickness of fin found zero ozone deflection and reduces global warming effect and low flammable of R407 C refrigerant better and thickness 1mm and copper fin has better result found on that analysis.

33. Omkar kurri, Ninad Mali, Parag Jain -In this paper did Optimization of fin by thermal and CFD analysis through ansys by fin materials Aluminum, Copper, Brass fin, Refrigerant R407C (Hydro fluoro carbon), R32 (Difluoromethane R125 (Pentafluoroethane),R134A(Tetrafluoroethane). Optimization on condenser found zero ozone deflection and reduces global warming effect and low flammable of R407 C refrigerant better and copper fin has better result found on that thermal analysis.

34. Chebrolu Vijay ,Sobhanadri Anantha- In this paper CFD Analysis done on air cooled condenser by fluids such as Nano fluid mixed with water, air, aluminum oxide. Copper and aluminum material of fin with helical tube and Variable mass flow rate and heat transfer coefficient. Aluminum oxide Nano fluid has found better cooling and copper tube best and 2.8 kg/s optimum mass flow rate in this analysis.

35. Aqive Ahmad ,Akhlesh Kumar Shakya-In this paper study a Rectangle, concave, trapezoidal fins had taken analysis with natural convection by using ansys software for analysis of heat transfer performance. Trapezoidal fin has found better result in this research.

36. G.Kiran Kumar-Heat transfer analyses done by varying geometry of fin rectangular and circular, materials, spacing between fins and variable thermal conductivity .on this research has better rectangular fin found.

37. Yogesh Rathore , Dhananjay Yadav-In this paper did Experimental analysis on condenser fin in RAC system .8 mm spacing fins offers lowest energy consumption and increasing heat transfer rate with increases COP condenser.

Result and Discussion

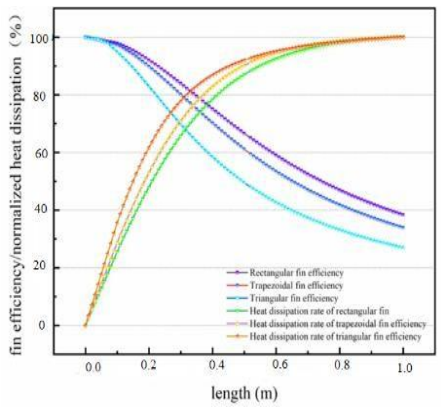


Fig. 4. *Fin efficiency/Temperature vs Length variation of rectangular, Trapezoidal and triangular fins*

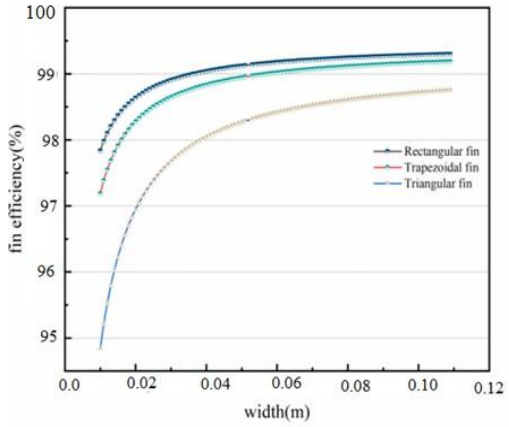


Fig. 5. *Fin efficiency vs. Width of variation of Rectangular, Trapezoidal and triangular fins*

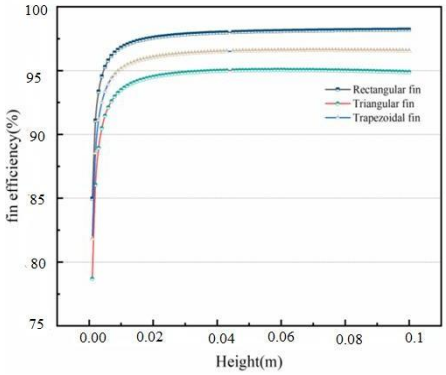


Fig. 5. *Fin efficiency vs. Height of variation of Rectangular, Trapezoidal and triangular fins*

Conclusion

In this review has concluded that the effect of refrigerant and its pressure and fluid velocity variation on Refrigeration system and components analyzed through CFD Analysis and Fins on different components of refrigeration system and heat transfer devices analyzed through Finite Element analysis experimentation. Different refrigerants and velocity and Fin geometry, material, weight of fins, numbers and its cost are different parameters effect on efficiency and effectives of fin on different environmental with safety conditions.

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