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Analytical Investigation of Fin Tube Evaporator by Using Different Refrigerant's

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ABSTRACT:
In this thesis, different configurations of fin tube evaporator are modeled in 3D modeling software Pro/Engineer. The temperature distribution, heat transfer rate is analyzed by thermal and CFD analysis done in Ansys. Thermal analysis is done on four different configurations are continuous fin, continuous fins with zig zag tubes, interrupted fin and interrupted fin with zig-zag tubes with different materials for evaporator Aluminum, Aluminum alloy 7075 and Copper CFD analysis is done by varying fluids R134a, R22a and R410a on all the configurations.

Key words:
Finite element analysis, fin tube evaporator, CFD analysis, thermal analysis.

I. INTRODUCTION:
An air conditioner (often referred to as AC) is a home appliance, system, or mechanism designed to dehumidify and extract heat from an area. The cooling is done using a simple refrigeration cycle. In construction, a complete system of heating, ventilation and air conditioning is referred to as "HVAC". Its purpose, in a building or an automobile, is to provide comfort during either hot or cold weather.

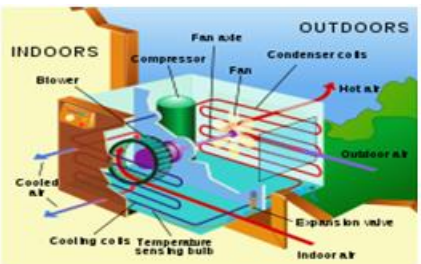

Fig1: A typical home air conditioning unit

EVAPORATOR:
It is in the evaporators where the actual cooling effect takes place in the refrigeration and the air conditioning systems. For many people the evaporator is the main part of the refrigeration system and they consider other parts as less useful. The evaporators are heat exchanger surfaces that transfer the heat from the substance to be cooled to the refrigerant, thus removing the heat from the substance. The evaporators are used for wide variety of diverse applications in refrigeration and air conditioning processes and hence they are available in wide variety of shapes, sizes and designs. They are also classified in different manner depending on the method of feeding the refrigerant, construction of the evaporator, direction of air circulation around the evaporator, application and also the refrigerant control.

TYPES OF EVAPORATORS OR CLASSIFICATION OF THE EVAPORATORS
In the large refrigeration and air conditioning plants the evaporator is used for chilling the water. In such cases shell and tube type of heat exchangers are used as the evaporators. In such plants the evaporators or the chillers are classified as:

1) Dry expansion type of evaporators
2) Flooded type of the evaporators

In case of the dry expansion type of chillers or evaporators the flow of the refrigerant to the evaporators is controlled by the expansion valve. The expansion valve allows the flow of the refrigerant depending on the refrigeration load.

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In case of the shell and tube type of evaporators the refrigerant flows along the tube side, while the substance to be chilled (usually water or brine) flows long the shell side. In case of the flooded the evaporator is filled with the refrigerant and constant level of the refrigerant is maintained inside it. In these evaporators or the chillers the refrigerant is along shell side while the substance to be chilled or freezer flows along the tube side of the heat exchanger.

1) Bare Tube Evaporators:

The bare tube evaporators are made up of copper tubing or steel pipes. The copper tubing is used for small evaporators where the refrigerant other than ammonia is used, while the steel pipes are used with the large evaporators where ammonia is used as the refrigerant. The bare tube evaporator comprises of several turns of the tubing, though most commonly flat zigzag and oval trombone are the most common shapes. The bare tube evaporators are usually used for liquid chilling. In the blast cooling and the freezing operations the atmospheric air flows over the bare tube evaporator and the chilled air leaving it used for the cooling purposes. The bare tube evaporators are used in very few applications, however the bare tube evaporators fitted with the fins, called as finned evaporators are used very commonly.

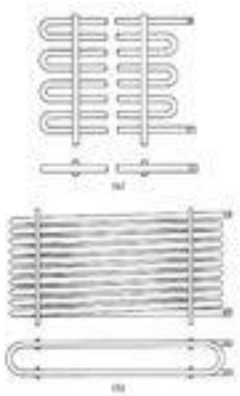

Fig2: Fin Tube evaporator Diagram

2) Plate Type of Evaporators:

In the plate type of evaporators the coil usually made up of copper or aluminum is embedded in the plate so as so to form a flat looking surface.

Externally the plate type of evaporator looks like a single plate, but inside it there are several turns of the metal tubing through which the refrigerant flows. The advantage of the plate type of evaporators is that they are more rigid as the external plate provides lots of safety. The external plate also helps increasing the heat transfer from the metal tubing to the substance to be chilled. Further, the plate type of evaporators are easy to clean and can be manufactured cheaply.

Fig3: Plate Type of Evaporators

II. LITERATURE REVIEW

In the paper by Jader R. Barbosa, etal[1], the purpose is to assess some aspects of the design of evaporators for household refrigeration appliances using Computational Fluid Dynamics (CFD). The evaporators under study are tube-fin 'no-frost' heat exchangers with forced convection on the air-side and a staggered tube configuration. The calculation methodology was verified against experimental data for the heat transfer rate, thermal conductance and pressure drop obtained for two evaporators with different geometries.

The average errors of the heat transfer rate, thermal conductance and pressure drop were 10%, 3% and 11%, respectively. The CFD model was then used to assess the influence of geometric parameters such as the presence and position of the electrical heater coil relative to the tubes, the fin configuration and the width of the by-pass clearance between the outer edge of the fins and the tube bank for conditions typical of the design of household refrigeration appliances. In the paper by Zine Aidoun, etal[2], Almost all forced convection air coolers use finned tubes.

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Coils have in this way become established as the heat transfer workhorse of the refrigeration industry, because of their high area density, their relatively low cost, and the excellent thermo physical properties of copper and aluminum, which are their principal construction materials. Compact coils are needed to facilitate the repackaging of a number of types of air conditioning and refrigeration equipment: a reduced volume effectively enables a new approach to be made to the modular design and a route towards improving performance and size is through appropriate selection of refrigerants, heat transfer enhancement of primary and secondary surfaces through advanced fin design and circuit configurations. Circuiting, although practically used on an empirical basis, has not yet received sufficient attention despite its potential for performance improvement, flow and heat transfer distribution, cost and operational efficiency. In the specific case of refrigeration and air conditioning, a confined phase changing refrigerant exchanges heat in evaporators with the cold room, giving up its heat.

III. PROBLEM DESCRIPTION:

The objective of this project is to make a 3D model of the fin tube evaporator and study the CFD and thermal behavior of the fin tube evaporator by performing the finite element analysis.3D modeling software (PRO-Engineer) was used for designing and analysis software (ANSYS) was used for CFD and thermal analysis.

MODELS

Case: 1	Continuous fin
Case: 2	Continuous fins with zig – zag tubes
Case: 3	Interrupted fin
Case: 4	Interrupted fin with zig-zag tubes

The Methodology Followed in the Project is As Follows:

- Create a 3D model of the fin tube evaporator assembly using parametric software pro-engineer.
- Convert the surface model into Para solid file and import the model into ANSYS to do analysis.
- Perform thermal analysis on the fin tube evaporator assembly for thermal loads.
- Perform CFD analysis on the existing model of the surface fin tube evaporator for Velocity inlet to find out the mass flow rate, heat transfer rate, pressure drop.

IV. INTRODUCTION TO CAD/CAE:

Computer-aided design (**CAD**), also known as **computer-aided design and drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation.

INTRODUCTION TO PRO-ENGINEER:

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

Different modules in pro/engineer:

Part design, Assembly, Drawing& Sheet metal.

INTRODUCTION TO FINITE ELEMENT METHOD:

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

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V. RESULTS AND DISCUSSIONS:

Models of fin tube evaporator using pro-e wildfire 5.0:

The fin tube evaporator is modeled using the given specifications and design formula from data book. The isometric view of fin tube evaporators shown in below figure. The fin tube evaporator outer casing body profile is sketched in sketcher and then it is sweep option and tubes are designed and assemble to in fin tube evaporator using extrude option.

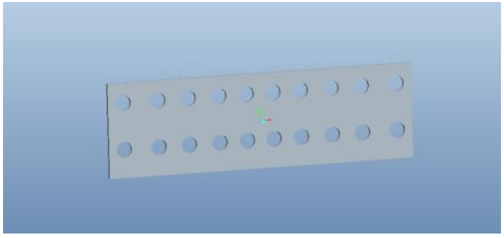


Fig: 3 fin tube evaporator3d model

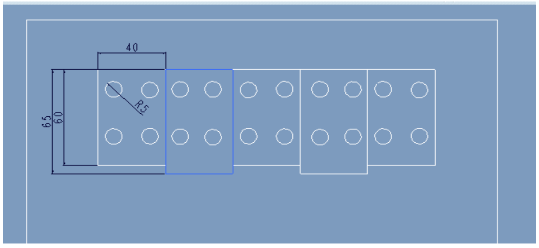


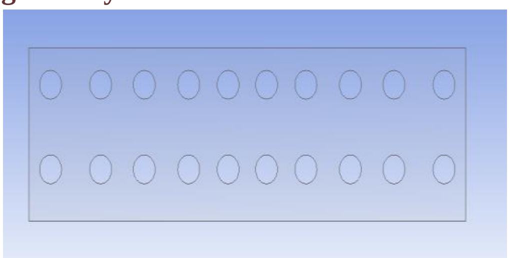
Fig: 4 Fin tube evaporator2D model

CFD ANALYSIS OF EVAPORATOR

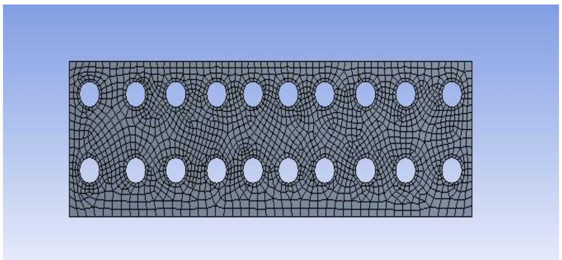
Case 1: continuous fin:Fluid - r134a

Ansys → workbench→ select analysis system → fluid flow fluent → double click →→select geometry → right click → import geometry → select browse →open part → ok→→ select mesh on work bench → right click →edit → select mesh on left side part tree → right click → generate mesh →

Fluid geometry



Meshed Model:



Select faces → right click → create named section → enter name → fluid inlet Select faces → right click → create named section → enter name → fluid outlet Select faces → right click → create named section → enter name → air inlet Select faces → right click → create named section → enter name → air outlet

Boundary conditions

Inlet temperatures(t)	253k,240k
Inlet pressure(p)	101325 pa
Mass flow inlet(kg/sec)	Fluid - 18.425kg/sec, air - 0.01875kg/sec

Select faces → right click → create named section → enter name →hot water outlet

Update project>setup>edit>model>select>energy equation (on)>ok

Materials> materials > new >create or edit >specify fluid material or specify properties > ok

Select fluid

R134a fluid properties

Density =1206 kg/m^3

Specific heat = 1340 j/kg k

Thermal conductivity =0.092(w/mm k)

viscosity = $271.08e^{-06}$ mm^2/s

Solution > solution initialization > hybrid initialization >done

Run calculations > no of iterations = 100> calculate > calculation complete>ok

Results>edit>select contours>ok>select location (inlet, outlet, wall.etc)>select pressure>

Pressure

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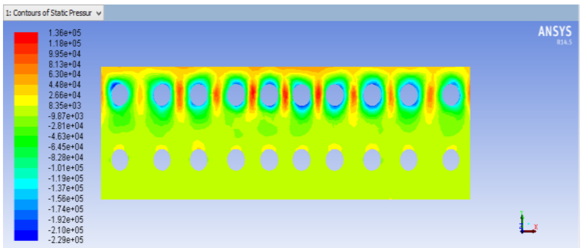
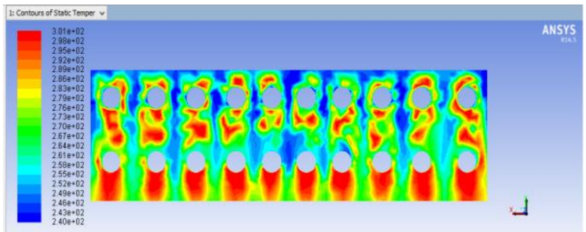
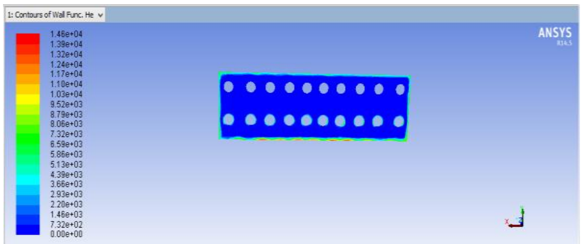


Temperature



Heat transfer coefficient



Mass flow rate

"flux report"

mass flow rate	(kg/s)
	0.018699992
air_outlet	-17.973562
fluid_inlet	18.425009
fluid_outlet	0
interior-____msbr	1.3007524
wall-____msbr	0
net	0.47014653

Heat transfer rate

"flux report"

total heat transfer rate	(w)
	-1137.3335
air_outlet	1397753.6
fluid_inlet	-1435694.8
fluid_outlet	0
wall-____msbr	0
net	-39078.458

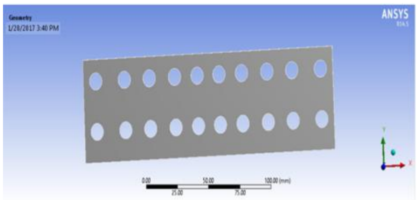
THERMAL ANALYSIS OF FIN TUBE EVAPORATOR

CASE 1: CONTINUOUS FIN

MATERIAL: ALUMINUM

Open work bench 14.5>select **steady state thermal** in analysis systems>select geometry>right click on the geometry>import geometry>select **IGES** file>open

Imported Model



Aluminum material properties

Thermal conductivity of aluminum = 35W/m-K
Specific heat =896 J/Kg K
Density = 0.0000027Kg/mm^3

Aluminum alloy 7075

Aluminum alloy material properties
Thermal conductivity of aluminum = 138W/m-K
Specific heat =880 J/Kg K
Density = 0.0000027Kg/mm^3

Copper

Thermal conductivity = 385w/m-k
Specific heat =385 j/kg k
Density = 0.000007764 kg/mm^3

Model >right click>edit>select generate mesh

Mesh details

Nodes	17361
Elements	2691

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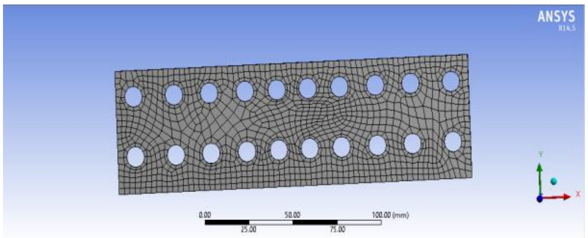


Boundary Conditions

T_1 =253 k

T_2 =240 k

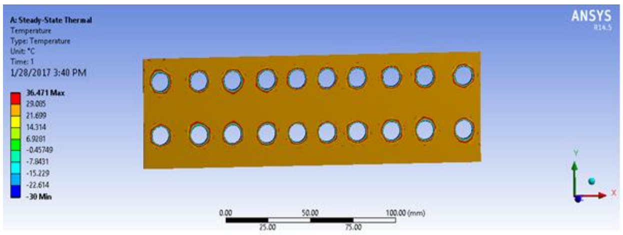
Select steady state thermal >right click>insert>select convection

Select steady state thermal >right click>insert>select heat flux

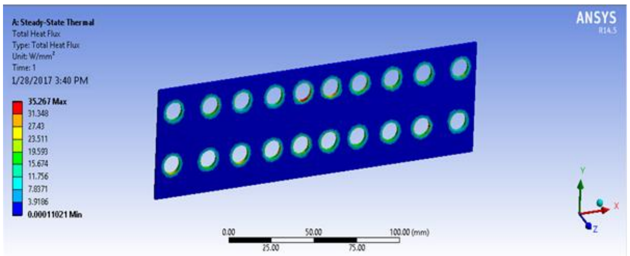
Select steady state thermal >right click>solve

Solution>right click on solution>insert>select temperature

Temperature



Heat flux



VI. RESULTS AND DISCUSSIONS

THERMAL ANALYSIS RESULT TABLE

Case 1: CONTINUOUS FIN

	Nodal temperature (K)	Heat flux (W/mm^2)
Aluminum	36.471	35.267
Aluminum alloy 7075	36.471	32.429
Copper	36.469	94.21

CASE 2: CONTINUOUS FINS WITH ZIG –ZAG TUBES

	Nodal temperature (K)	Heat flux (W/mm^2)
Aluminum	43.901	43.972
Aluminum alloy 7075	43.901	43.51
Copper	43.901	117.67

CASE 3: INTERRUPTED FIN

	Nodal temperature (K)	Heat flux (W/mm^2)
Aluminum	37.696	12.6
Aluminum alloy 7075	37.696	12.103
Copper	37.696	35.167

CASE 4: INTERRUPTED FIN WITH ZIG-ZAG TUBES

Material	Nodal temperature (K)	Heat flux (W/mm^2)
Aluminum	37.568	9.2475
Aluminum alloy 7075	37.56	8.9094
Copper	37.637	25.888

THERMAL ANALYSIS RESULT TABLE

Case 1: CONTINUOUS FIN

Fluid	Pressure (N/mm^2)	Temperature (K)	Mass flow rate (Kg/sec)	Heat transfer (W)	Heat transfer coefficient
R134a	1.36e+05	3.01e+02	0.470146	39078.458	1.46e+04
R22a	1.56e+05	3.01e+02	0.712459	54671.702	1.68e+04
R410a	1.17e+05	3.01e+02	0.577493	53038.791	1.84e+04

CASE 2: CONTINUOUS FINS WITH ZIG –ZAG TUBES

Fluid	Pressure (N/mm^2)	Temperature (K)	Mass flow rate (Kg/sec)	Heat transfer (W)	Heat transfer coefficient
R134a	1.22e+05	3.00e+02	0.571763	23658.998	1.20e+04
R22a	1.39e+05	3.00e+02	0.705393	40417.525	1.14e+04
R410a	1.05e+05	3.00e+02	0.549980	29575.666	1.45e+04

CASE 3: INTERRUPTED FIN

Fluid	Pressure (N/mm^2)	Temperature (K)	Mass flow rate (Kg/sec)	Heat transfer (W)	Heat transfer coefficient
R134a	1.62e+05	3.00e+02	0.1237174	10499.786	6.23e+04
R22a	1.86e+05	3.00e+02	0.148058	11481.063	5.92e+04
R410a	1.42e+05	3.00e+02	0.0558251	11008.721	7.52e+04

CASE 4: INTERRUPTED FIN WITH ZIG-ZAG TUBES

Fluid	Pressure (N/mm^2)	Temperature (K)	Mass flow rate (Kg/sec)	Heat transfer (W)	Heat transfer coefficient
R134a	1.80e+05	3.00e+02	0.146532	7041.874	8.56e+04
R22a	1.57e+05	3.00e+02	0.145493	12693.491	9.59e+04
R410a	2.79e+05	3.00e+02	0.118523	6379.4	1.08e+04

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CONCLUSION:

In this thesis, different configurations of fin tube evaporator are modeled in 3D modeling software Pro/Engineer. Different configurations are continuous fin, continuous fins with zig zag tubes, interrupted fin and interrupted fin with zig-zag tubes with different materials for evaporator Aluminum, Aluminum alloy 7075 and Copper and different fluids R134a, R22a and R410a. Thermal and CFD analysis is done in Ansys. By observing the thermal analysis results, the configuration of fin tube evaporator with configuration of continuous fins and zig zag tubes has more heat transfer rate than other configurations for copper materials. By observing the CFD analysis results, heat transfer, mass flow rate is more for continuous fins and zig zag tubes configuration. The heat transfer coefficient is more for configuration of interrupted fin with zig-zag tubes. The results better for fluid R22a.

So it can be concluded that to get better performance, using continuous fins and zig zag tubes configuration, fluid R22a and copper are preferable.

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