

## IMPROVING THE HEAT TRANSFER RATE OF AC EVAPORATOR BY OPTIMIZING MATERIAL

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### ABSTRACT

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 complete using a simple refrigeration cycle. In construction, a complete system of heating, ventilation and air conditioning is referred to as "HVAC". Its use, in a building or an automobile, is to present comfort during either hot or cold weather the most common refrigeration cycle use an electric motor to drive a compressor. In an automobile, the compressor is driven by a belt over a pulley, the belt being driven by the engine's crankshaft (similar to the driving of the pulleys for the alternator, power steering, etc.).An evaporator is use in an air-conditioning system or refrigeration system to allow a compressed cooling chemical, such as Freon or R-134A, to evaporate from liquid to gas while enthralling heat in the process. It is also use to remove water or other liquids from mixtures. The process of evaporation is widely used to concentrate foods and chemicals as well as salvage solvents. In the concentration process, the goal of evaporation is to vaporize most of the water from a solution which contains the desired product. In this thesis, dissimilar shapes of fins in fin tube evaporator are modeled in 3D modeling software Pro/Engineer. The fins considered are rectangular fin, circular fin a internal finned. The mass flow rate and heat transfer rate are analyzed by CFD analysis completed in ANSYS. CFD analysis is completed by varying fluids R407C, R404A and R22A on all the models. The inputs of CFD analysis are velocity and pressure and the results determined are Pressure, Velocity, Mass Flow Rate, Heat Transfer Rate and Heat Transfer Coefficient..

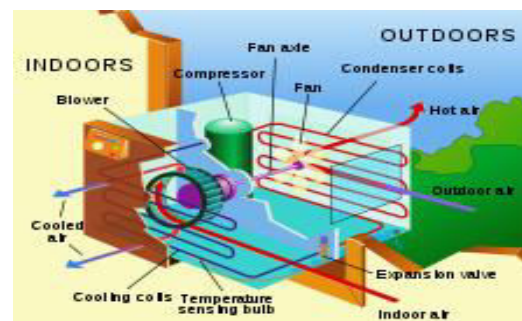
**Keywords:** ANSYS, CREO, Pro –E, Thermal Analysis

### 1. INTRODUCTION

#### 1.1Air Conditioning:

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.



**Fig 1 . A typical home air conditioning unit**

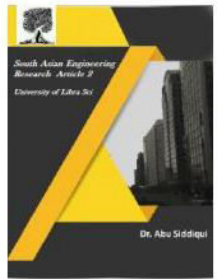


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## 1.2 Evaporator:

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.

In the domestic refrigerators the evaporators are commonly known as the freezers since the ice is made in these compartments. In case of the window and split air conditioners and other air conditioning systems where the evaporator is directly used for cooling the room air, it is called as the cooling coil. In case of large refrigeration plants and central air conditioning plants the evaporator is also known as the chiller since these systems are first used to chill the water, which then produces the cooling effect.

In the evaporator the refrigerant enters at very low pressure and temperature after passing through the expansion valve. This refrigerant absorbs the heat from the substance that is to be cooled so the

refrigerant gets heated while the substance gets cooled. Even after cooling the substance the temperature of the refrigerant leaving the evaporator is less than the substance. The refrigerant leaves the evaporator in vapor state, mostly superheated and is absorbed by the compressor.

### 1.2.1 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

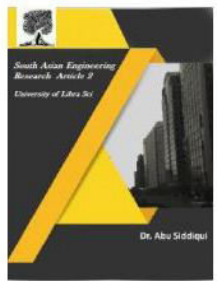
In case of the dry expansion type of chillers or evaporators the flow of the refrigerant to the evaporators is controlled by the expansion valve. The expansion valve allows the flow of the refrigerant depending on the refrigeration load. In case of the shell and tube type of evaporators the refrigerant flows along the tube side, while the substance to be chilled (usually water or brine) flows along 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.

### 1.3 Classification of the Evaporators Based on the Construction:

The evaporators used for the refrigeration and the air conditioning applications have different types of construction depending on



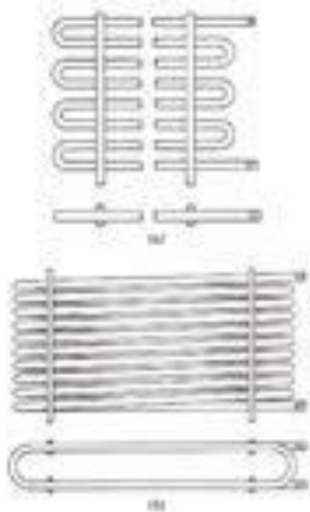
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the application. Based on their construction the various types of evaporators are:

### 1.3.1 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.



**Fig 2 Bare Tube Evaporator**

### 1.3.2 Plate Type of Evaporators

The plate type of evaporators the coil usually made up of copper or aluminum is embedded in the plate so as 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.

The plate type heat exchangers can be easily formed into various shapes as per the requirement. Thus in the household refrigerators and the deep freezers, where they are used most commonly, they can be converted into the box shape to form the closed enclosure, where various food can be kept in the frozen state. The plates can also be welded together forming the bank of the plate type of evaporators that can be used the larger evaporators of higher capacities.

Plate types of evaporators provide excellent shelves in the freezers and similar applications. They can be used as the as the partitions in the freezers, frozen food display cases, ice cream cabinets, soda fountains and others. Due to various advantages and flexibility offered by the plate type of evaporators, they are used extensively.

### 1.3.3 Plate Type of Evaporators



**Fig 3 Plate Type of Evaporator**

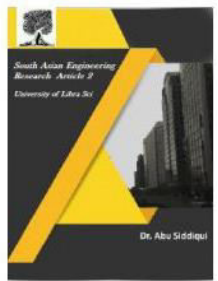


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The shell and tube types of evaporators are used in the large refrigeration and central air conditioning systems. The evaporators in these systems are commonly known as the chillers. Depending on the direction of the flow of the refrigerant in the shell and tube type of chillers, they are classified into two types: dry expansion type and flooded type of chillers. In dry expansion chillers the refrigerant flows along the tube side and the fluid to be chilled flows along the shell side. The flow of the refrigerant to these chillers is controlled by the expansion valve.

### 1.3.4 Finned Evaporators

The finned evaporators are the bare tube type of evaporators covered with the fins. When the fluid (air or water) to be chilled flows over the bare tube evaporator lots of cooling effect from the refrigerant goes wasted since there is less surface for the transfer of heat from the fluid to the refrigerant. The fluid tends to move between the open spaces of the tubing and does not come in contact with the surface of the coil, thus the bare tube evaporators are less effective. The fins on the external surface of the bare tube evaporators increases the contact surface of the of the metallic tubing with the fluid and increase the heat transfer rate, thus the finned evaporators are more effective than the bare tube evaporators.

The fins are the external protrusions from the surface of the coil and they extend into the open space. They help removing the heat from the fluid that otherwise would not have come in contact with the coil.

For the fins to be effective it is very important that there is very good contact between the coil and the fins. In some cases

the fins are soldered directly to the surface of the coil and in other cases the fins are just slipped over the surface of the fins and then they are expanded thus ensuring a close thermal contact between the two. Though the fins help increase the heat transfer, rate, adding them beyond certain numbers won't produce any additional benefits, hence only certain number of fins should be applied on the external surface of the tube.

The finned evaporators are most commonly used in the air conditioners of almost all types like window, split, packaged and the central air conditioning systems. In these systems the finned evaporator is popularly known as the cooling coil. The hot room air flows over the finned evaporator or the cooling coil, gets chilled and enters the room to produce the cooling effect. In window a/c the finned evaporators is located behind the beautifully looking grill. In the wall mounted split unit it located behind the front grill of the indoor unit.

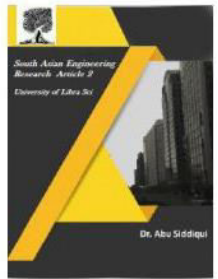
To further increase the effectiveness of heat transfer from the evaporators, the tubing are also given internal fins. These fins are made by forming different internal cross section shapes at the time of the manufacture of the tubing. Some methods of internal and external fins are shown in the figure below.



Fig 4 Finned Evaporator



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### 1.3.5 Shell and Tube types of Evaporators

The shell and tube types of evaporators are used in the large refrigeration and central air conditioning systems. The evaporators in these systems are commonly known as the chillers. The chillers comprise of large number of the tubes that are inserted inside the drum or the shell. Depending on the direction of the flow of the refrigerant in the shell and tube type of chillers, they are classified into two types: dry expansion type and flooded type of chillers. In dry expansion chillers the refrigerant flows along the tube side and the fluid to be chilled flows along the shell side. The flow of the refrigerant to these chillers is controlled by the expansion valve. In case of the flooded type of evaporators the refrigerant flows along the shell side and fluid to be chilled flows along the tube. In these chillers the level of the refrigerant is kept constant by the float valve that acts as the expansion valve also.

## 2. MODELLING OF EVAPORATOR

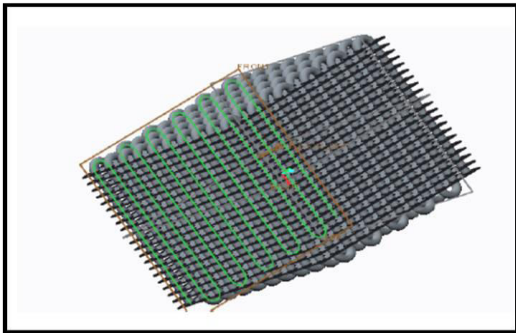


Fig 5 3D Model of evaporator

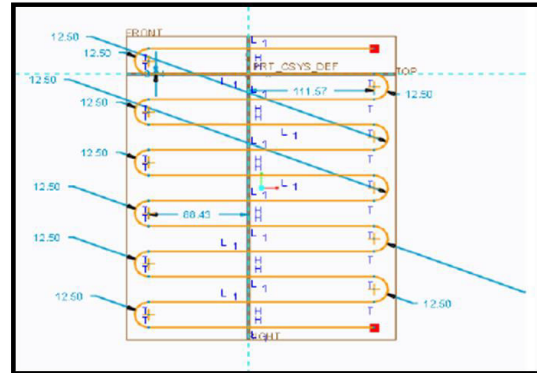


Fig 6 2D Model of Evaporator

### 2.1 CFD Analysis of Finned Tube Evaporator Condition -Circular Fins

#### 2.1.1 FLUID -R407C

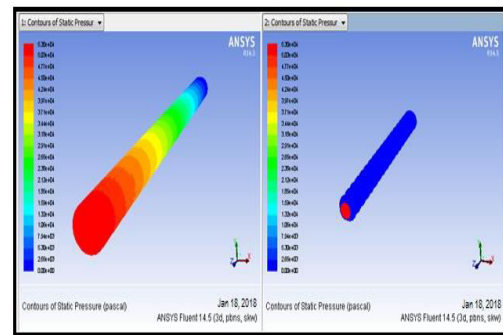


Fig 7 Pressur

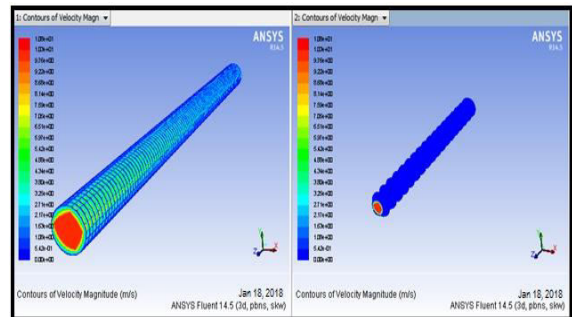


Fig 8 Velocity

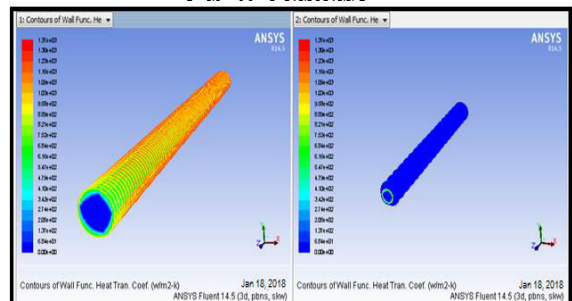


Fig 9 Heat transfer Co Efficient

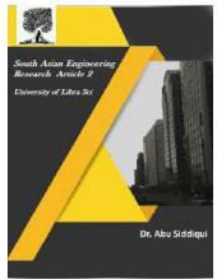


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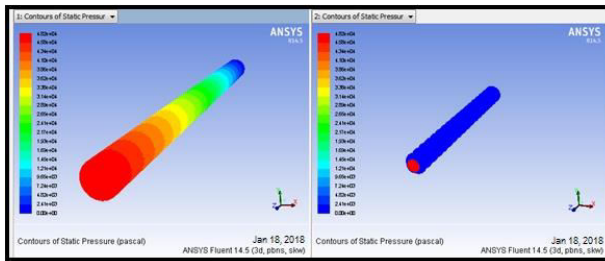
contact_region-src	0
contact_region-trg	0
inlet	1.4757769
interior-___msbr	0
interior-solid	150.58551
outlet	-1.4759138
wall-12	0
wall-13	0
wall-7	0
wall-7-shadow	0
wall-___msbr	0
-----	
Net	-0.00013685226

**Fig 10 Mass Flow Rate**

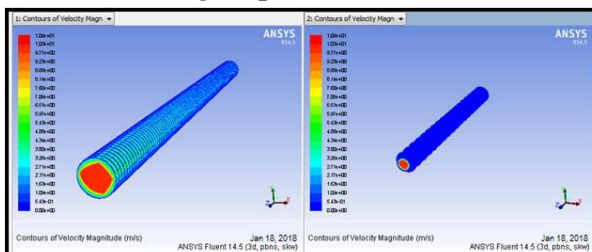
<b>Total Heat Transfer Rate (w)</b>	
-----	
contact_region-src	0
contact_region-trg	0
inlet	4853.6831
outlet	-4843.708
wall-12	0
wall-13	0
wall-7	10.456677
wall-7-shadow	-10.458258
wall-___msbr	-10.526047
-----	
Net	-0.55252934

**Fig 11 Heat Transfer rate**

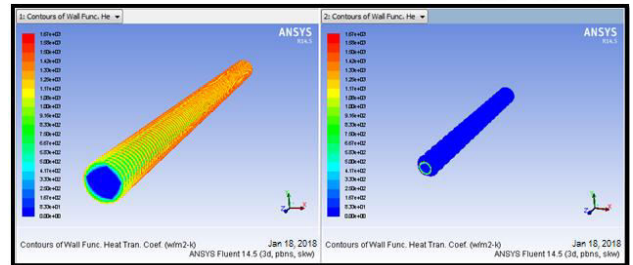
## 2.1.2 FLUID -R404A



**Fig 12 pressure**



**Fig 13 Velocity**



**Fig 14 Heat Transfer Co Efficient**

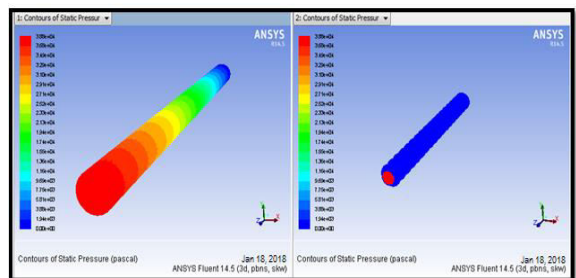
<b>Mass Flow Rate (kg/s)</b>	
-----	
contact_region-src	0
contact_region-trg	0
inlet	1.3560489
interior-___msbr	0
interior-solid	138.35242
outlet	-1.3564129
wall-12	0
wall-13	0
wall-7	0
wall-7-shadow	0
wall-___msbr	0
-----	
Net	-0.00036394596

**Fig 15 Mass Flow Rate**

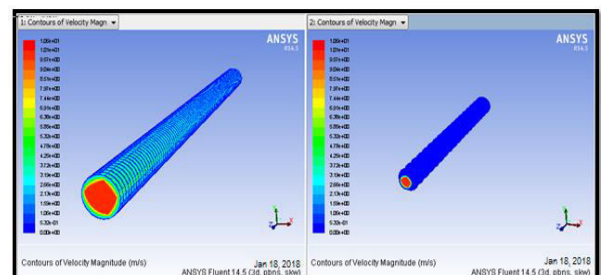
<b>Total Heat Transfer Rate (w)</b>	
-----	
contact_region-src	0
contact_region-trg	0
inlet	7033.8267
outlet	-7022.9478
wall-12	0
wall-13	0
wall-7	12.725677
wall-7-shadow	-12.731516
wall-___msbr	-12.819903
-----	
Net	-1.9468365

**Fig 16 Heat Transfer Rate**

## 2.1.3 FLUID -R22A



**Fig 17 pressure**



**Fig 18 velocity**

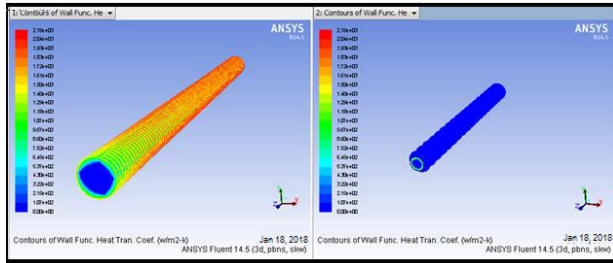
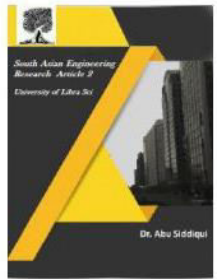


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**Fig 19 Heat Transfer Co Efficient**

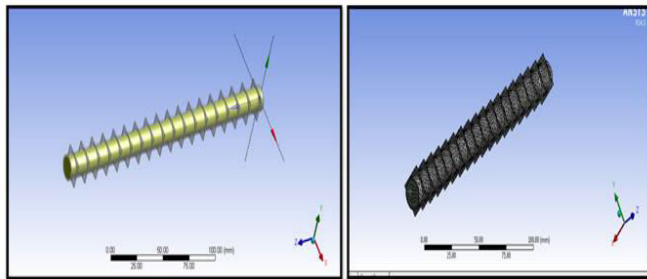
contact_region-src	0
contact_region-trg	0
inlet	1.564662
interior-__msbr	0
interior-solid	159.6331
outlet	-1.5654905
wall-12	0
wall-13	0
wall-7	0
wall-7-shadow	0
wall-__msbr	0
Net	-0.00082850456

**Fig 20 Mass Flow Rate**

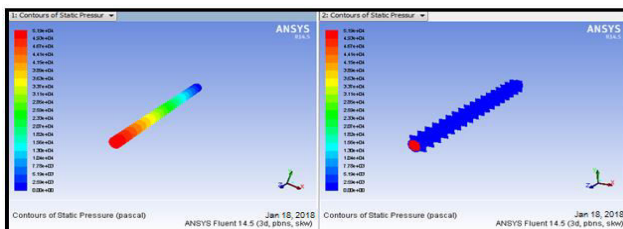
Total Heat Transfer Rate	(w)
contact_region-src	0
contact_region-trg	0
inlet	5529.5166
outlet	-5515.7607
wall-12	0
wall-13	0
wall-7	16.817842
wall-7-shadow	-16.819735
wall-__msbr	-16.806288
Net	-3.0523205

**Fig 21 Heat Transfer Rate**

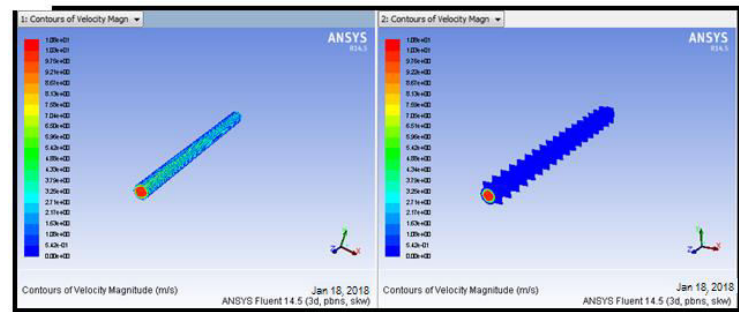
## 2.2 Condition -Rectangular Fins 2.2.1 FLUID -R407C



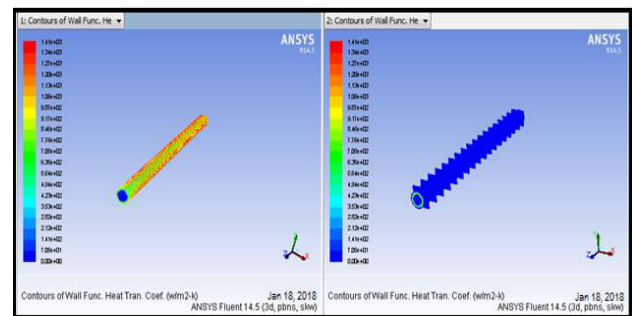
**Fig 22 Imported And Meshed Model**



**Fig 23 Pressure**



**Fig 24 Velocity**



**Fig 25 Heat Transfer Co Efficient**

contact_region-src	0
contact_region-trg	0
inlet	1.4527532
interior-__msbr	0
interior-solid	-149.54221
outlet	-1.4523633
wall-12	0
wall-13	0
wall-7	0
wall-7-shadow	0
wall-__msbr	0
Net	0.00038993359

**Fig 26 Mass Flow Rate**

Total Heat Transfer Rate	(w)
contact_region-src	0
contact_region-trg	0
inlet	6376.1357
outlet	-6363.9346
wall-12	0
wall-13	0
wall-7	10.591985
wall-7-shadow	-10.587517
wall-__msbr	-10.673385
Net	1.5322552

**Fig 27 Heat Transfer Rate**

## 2.2.2 FLUID -R404A

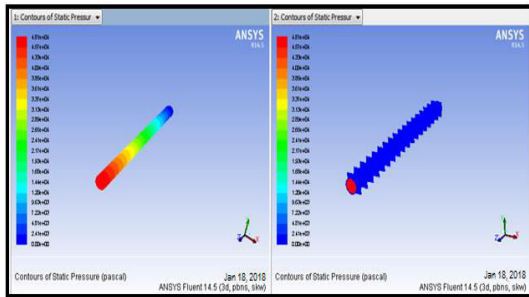


Fig 28 Pressure

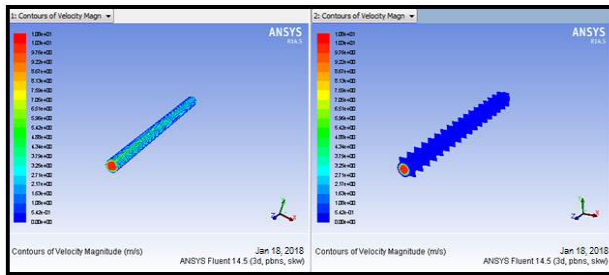


Fig 29 Velocity

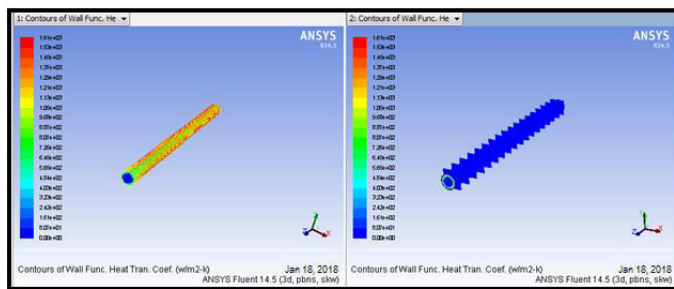


Fig 30 Heat Transfer Co efficient

contact_region-src	0
contact_region-trg	0
inlet	1.3348932
interior-msbr	0
interior-solid	-137.40962
outlet	-1.3345335
wall-12	0
wall-13	0
wall-7	0
wall-7-shadow	0
wall-msbr	0
Net	0.00035977364

Total Heat Transfer Rate	(w)
contact_region-src	0
contact_region-trg	0
inlet	7304.5371
outlet	-7290.5889
wall-12	0
wall-13	0
wall-7	12.099855
wall-7-shadow	-12.100044
wall-msbr	-12.187788
Net	1.7594652

Fig 31 Mass Flow Rate and Heat transfer Rate

## 2.2.3 FLUID -R22A

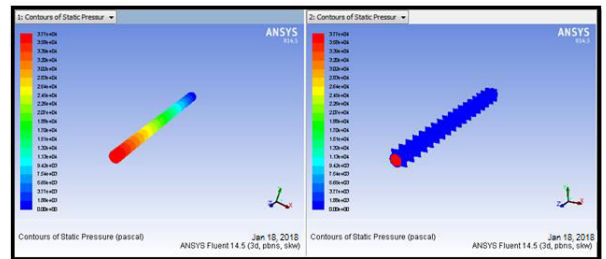


Fig 32 Pressure

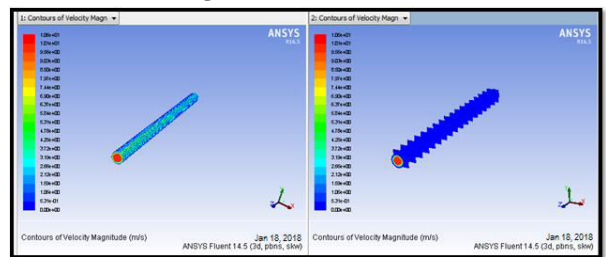


Fig 33 Velocity

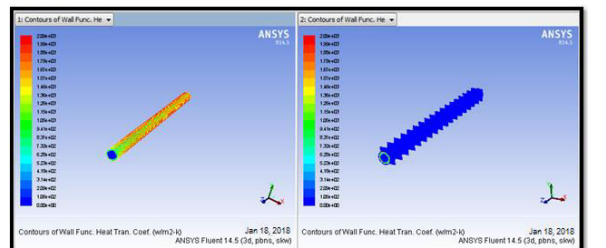


Fig 34 Heat Transfer Co efficient

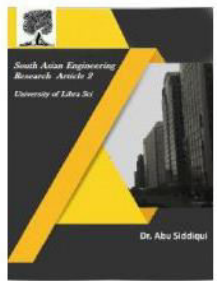
contact_region-src	0
contact_region-trg	0
inlet	1.5402519
interior-msbr	0
interior-solid	-158.5845
outlet	-1.5397581
wall-12	0
wall-13	0
wall-7	0
wall-7-shadow	0
wall-msbr	0
Net	0.00049376488

Fig 35 mass flow rate

Total Heat Transfer Rate	(w)
contact_region-src	0
contact_region-trg	0
inlet	5443.251
outlet	-5425.8115
wall-12	0
wall-13	0
wall-7	15.765675
wall-7-shadow	-15.765544
wall-msbr	-15.742006
Net	1.6975775



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## 2.3 Thermal Analysis of Finned Tube Evaporator Material – Aluminum Condition –Circular

### 2.3.1.1 FLUID -R407C

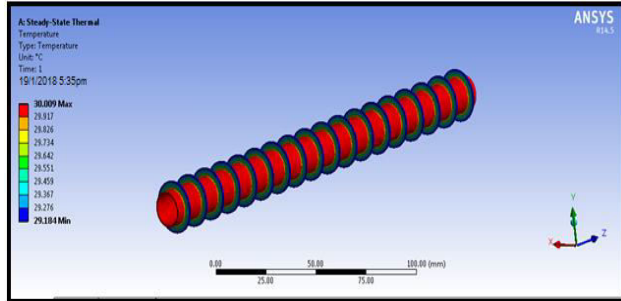


Fig 36 Temperature

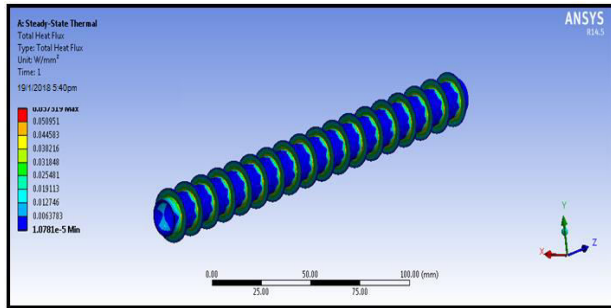


Fig 37 Heat Flux

### 2.3.1.2 FLUID -R404A

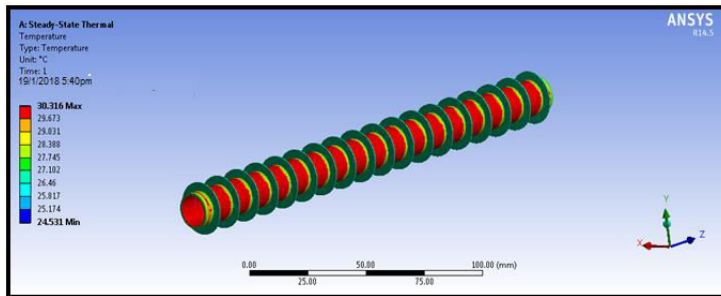


Fig 38 Temperature

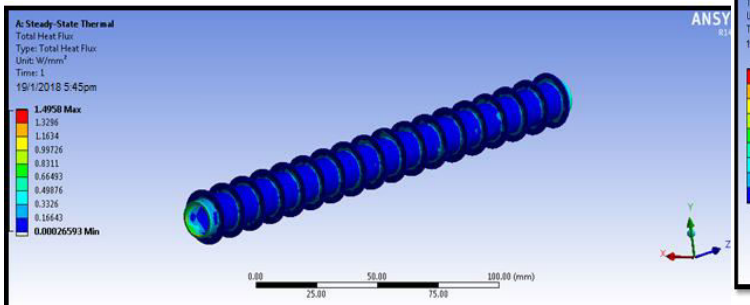


Fig 39 Heat Flux

### 2.3.1.3 FLUID -R22A

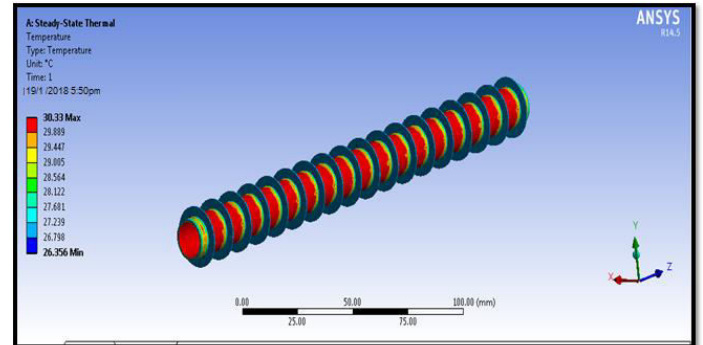


Fig 40 temperature

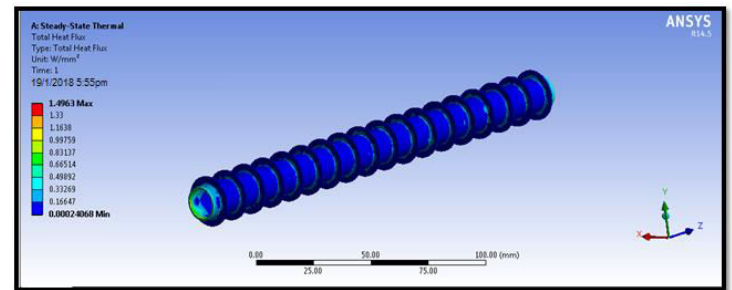


Fig 41 Heat Flux

## 2.3.2 Condition –Rectangular Fins

### 2.3.2.1 FLUID -R407C

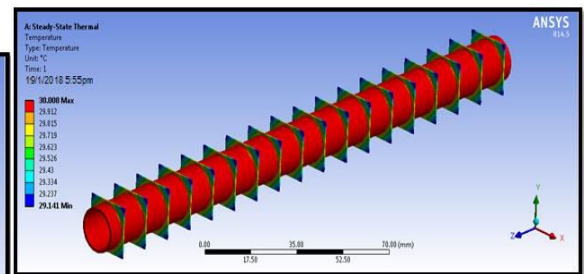


Fig 42 Temperature

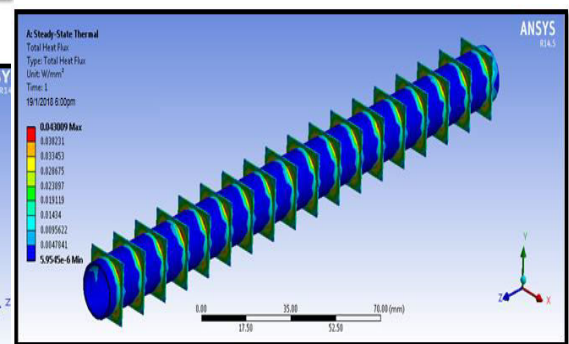
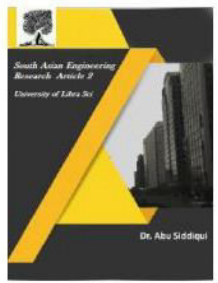


Fig 43 Heat flux



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## 2.3.2.2 FLUID -R404A

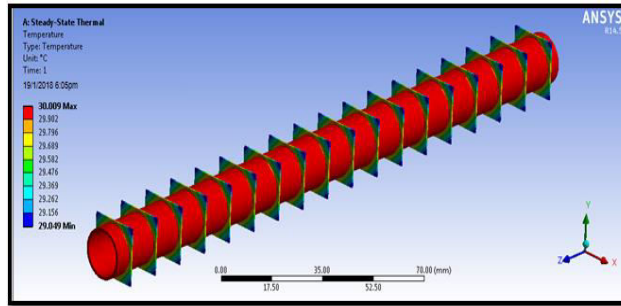


Fig 44 Temperature

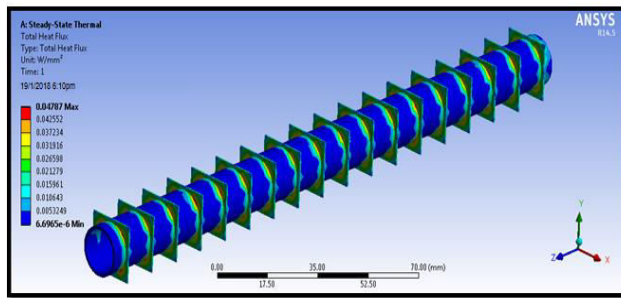


Fig 45 Heat Flux

## 2.3.2.3 FLUID -R22A

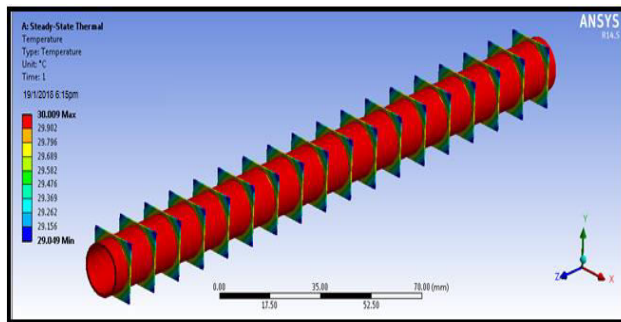


Fig 46 Temperature

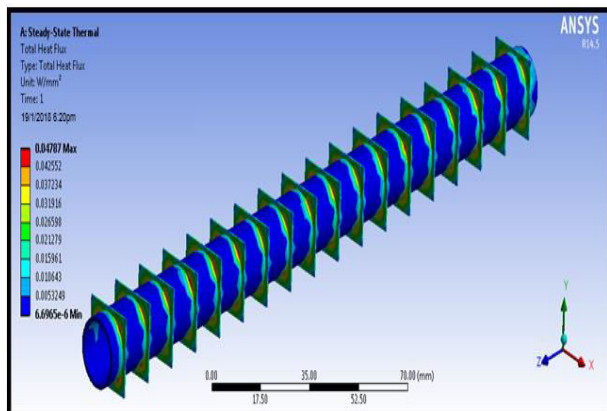


Fig 47 Heat Flux

## 3. RESULTS AND DISCUSSION

### 3.1 CFD RESULTS

CONDITION	FLUID	PRESSURE (Pa)	VELOCITY (m/s)	HEAT TRANSFER COEFFICIENT (W/m <sup>2</sup> K)	Mass flow rate (kg/se)	Heat transfer Rate (w)
CIRCULAR	R407C	5.30e+04	1.08e+01	1.37e+03	0.0001	0.55
	R404A	4.82e+04	1.09e+01	1.67e+03	0.0003	1.94
	R22A	3.88e+04	1.06e+01	2.15e+03	0.0008	3.05
RECTANGULAR	R407C	5.19e+04	1.083e+01	1.41e+03	0.0003	1.53
	R404A	4.81e+04	1.08e+01	1.61e+03	0.0003	1.75
	R22A	3.77e+04	1.07e+01	2.09e+03	0.0004	1.69

### 3.2 THERMAL ANALYSIS RESULTS

#### 3.2.1 MATERIAL –ALUMINUM

CONDITION	FLUID	Temperature (K)	Heat flux (w/mm <sup>2</sup> )
CIRCULAR	R407C	30.009	0.057319
	R404A	30.316	1.4958
	R22A	30.33	1.4963
RECTANGULAR	R407C	30.008	0.043009
	R404A	30.009	0.04787
	R22A	30.011	0.058602

#### 3.2.2 MATERIAL –COPPER

CONDITION	FLUID	Temperature (K)	Heat flux (w/mm <sup>2</sup> )
CIRCULAR	R407C	30.004	0.063727
	R404A	30.025	0.38331
	R22A	30.006	0.094924
RECTANGULAR	R407C	30.003	0.048092
	R404A	30.004	0.054321
	R22A	30.005	0.068739

## 4. CONCLUSION

In this thesis, different shapes of fins in fin tube evaporator are modeled in 3D modeling software Pro/Engineer. The fins considered are rectangular fin, circular fin.



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The mass flow rate and heat transfer rate are analyzed by CFD analysis done in ANSYS.

CFD analysis is done by varying fluids R407c, R404a and R22a on all the models. CFD analysis is done in ANSYS. By observing the CFD analysis results, heat transfer coefficient, heat transfer rate, mass flow rate are more for circular fin. Heat transfer coefficient and pressure are more for circular fin. By comparing the fluids, heat transfer rate, mass flow rate are more for R22a, heat transfer coefficient is more for R22a and outlet pressure is more for 407c. By observing the thermal analysis results, the heat flux is more for circular fin than rectangular fins. R22a has more heat flux than R407c and R404a. So using circular fins and R22a is better. So we can conclude that aluminum is the better material for fin tube evaporator.

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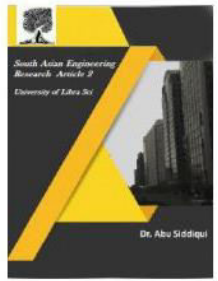


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