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Thermal Analysis of Extracting Waste Heat from the Engine Exhaust and Reutilizing in Car Air Conditioning

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Abstract— *To improve the performance of cars i.e enviromental quality, fuel, economy etc. It is required to use of high technology research and design tools. One of the tool is Ansys. Whether it is the study of external flow or internal flow over the body. Ansys helps engineers to understand better about the physical flow processes, and in turn to design improved vehicles. Working with the software by choosing applications where it is difficult to check the validity of the results, so that the engineers can see the strength and weakness of given computation technique against the background of known, exact analytical solution. In today generation where new designs, speed, cooling system is mandatory in cars, likewise air condition is also necessary to provide cooling comfort in cars. As cars having air condition which is more likely vapour compression system which uses some amount of fuel which contains HCFC refrigerants, which contribute to depletion of earth's ozone layer. HCFCs are due to be phased out and are largely being replaced by ozone friendly HFCs. In replacement vapour absorption system is used which uses heat as a source in generator. Generator is a main component of vapour absorption refrigerator which replaces compressor as a main unit in cars. In this project thermal analysis of vapour absorption system is done. The different component of vapour absorption system which includes generator, condensor, evaporator, absorber are analised in ansys at different conditions, materials, and design model. Models being converted from 3 dimension to 2 dimension solid to be analyzed in APDL software where the different material of fins and tube is analysed according to the different conditions and effect of atmospheric air is taken into account.*

Keywords—*VARS, VCRS, COP, APDL, Convention heat source.*

I. INTRODUCTION

In current scenario, the main concern is about to save energy for future, so energy efficient is needed to be in account. Energy efficiency is goal to reduce the amount of energy required to provide products and services in future. Reducing energy use reduces energy costs and may result in a financial cost savings to consumers if the energy savings offset any additional costs of implementing an energy efficient technology. In many countries energy efficiency is also seen to have a national benefit because it can used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted. Much of this research focuses on technologies that can improve the efficiency of cars.

Working with software ansys program has two levels: the begin level and the processor level. In the begin level, a ansys processors can be entered. A processor is a collection of functions and routines for the specific purposes. Clearing the database or changing the file assignment can be done from the begin level.

There are three processor that are used most frequently

1. Preprocessor
2. Processor
3. General Processor

The Preprocessor contains commands needed to build a model.

- Define element types and options
- Define element real constraints
- Define material properties
- Create model geometry
- Defines meshing control
- Mesh the object created

The solution processor has the commands that allow to apply boundary conditions and loads. Once the information is made available to the processor it solves the nodal solutions. For example, for structural problems displacement boundary conditions and forces are define or for heat transfer problems boundary temperatures or convection surfaces are define.

The general postprocessor contains the commands that allow to list and display results of analysis.

- Read results data from results file
- Read element results data
- Plots results
- List results

There are other processors like time-history postprocessor contains the commands that allow to review result over time in a transient analysis at certain point in the model. The design optimization processor allows the user to perform a design optimization analysis.

In my thesis work 3D model of the components of vapour absorption system is converted to 2D ansys APDL which stands for Ansys Parametric Design Language, it is a scripting language that use to automate common task.

II. DESIGN CALCULATIONS OF VARS

Generator

The calculations of air conditioning system have been done earlier for car which runs at 0.80 TR and 4.80 KW heat for refrigerant to evaporate. Therefore generator is designed for capacity of 4.80 KW with temperature of 95°C and pressure 20 bars. And hence generator has been designed for 2400 RPM at 314°C. The space available in the automobile to installed generator is 48cm long, 10cm wide and 6cm height.

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Assuming inside diameter and outside diameter of steel tube is 23 mm and 26 mm.

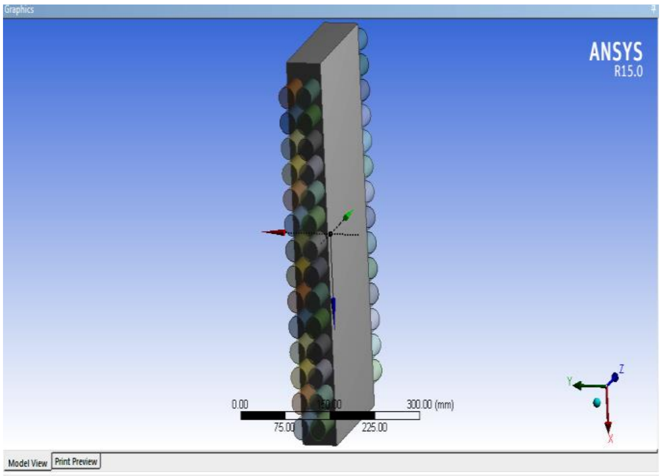

Fig. 1. Design of generator.

LMTD = Log mean temperature difference
Assuming cross flow type heat exchanger arrangement for heating process

$$\text{LMTD} = \frac{(\text{Th}_i - \text{Tc}_o) - (\text{Th}_o - \text{Tc}_i)}{\ln\left(\frac{\text{Th}_i - \text{Tc}_o}{\text{Th}_o - \text{Tc}_i}\right)}$$

Where,

Th_i = Inlet Temperature of hot exhaust gas.
Th_o = Outlet Temperature of cold exhaust gas.
Tc_i = Inlet Temperature of strong solution.
Tc_o = Outlet Temperature of ammonia vapour.

To find Th_o
Heat given to generator by exhaust heat at 2400 RPM
T= 314°C & mass flow rate = 0.03045 kg/s
$t_{ho} = t_{out}$ = 163°C
LMTD = 132.89°C
The external heat transfer area(A) required
A = 0.218 m^3
L=2.68m
Number of tube
N = 45
Number of row
R = 3
Number of tubes per row
R_t = 15

Condenser

The standard size of tube usually ranges from 6 mm to 18 mm outside diameter, depending upon size of condenser. Assuming inside and outside diameter of tube is 13 mm to 16 mm and also dimension of condenser 420 mm width, 400 mm height and 48 mm depth.

Design calculation

It needs 2.9051 KW heat rejection for running 0.80 TR air conditioning in car from previous calculation. Therefore condenser is designed to have capacity 2.90 KW.

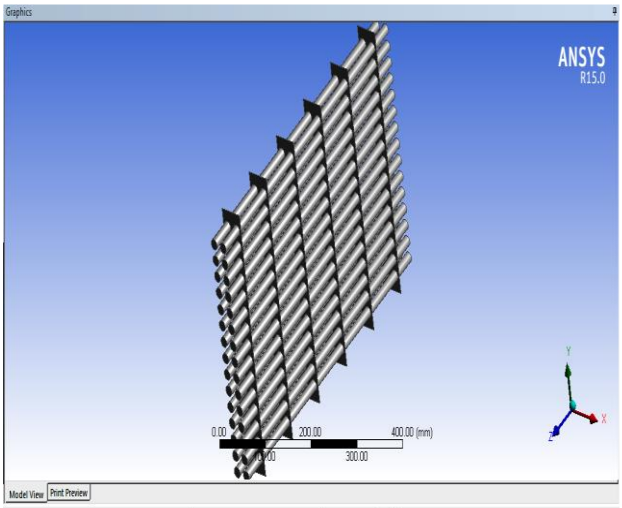

Fig. 2. Design of condenser.

Log mean temperature difference

Assuming cross flow type heat exchanger arrangement for condensation process.

$$\text{LMTD} = \frac{(\text{Th}_i - \text{Tc}_o) - (\text{Th}_o - \text{Tc}_i)}{\ln\left(\frac{\text{Th}_i - \text{Tc}_o}{\text{Th}_o - \text{Tc}_i}\right)}$$

Th_i = inlet temperature of refrigerant into condenser
Th_o = outlet temperature of refrigerant from condenser
Tc_o = outlet temperature of air after crossing the condenser
Tc_i = inlet temperature of air before crossing the condenser
LMTD = 7.3°C
The total external heat transfer area required
A_t = 6.14 m^2
Inside area
A_i = 0.511
Length of tube
L= 12.51 m
Number of tube
N = 29.78
Number of row
R = 2.95
Number of tube per row
R_t = 16.66
Thickness of fins
f_t=0.105 mm
Space between fins
f_s = 1.89 mm

Absorber

Here a vertical cooled fin tube type heat exchanger is used. Assuming inside diameter and outside diameter as 23 mm and 26 mm, absorber width, height and depth are 580 mm, 420 mm and 50 mm.

Design calculation

The function of absorber is important in vapour absorption refrigeration system. The system needs 4.06 kJ/s heat for running air condition system. Hence, an absorber is designed for 4.06 kJ/s.

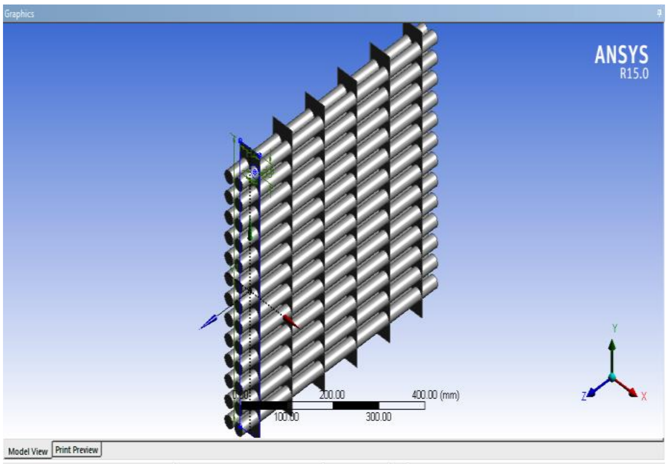

Fig. 3. Design of absorber.

Log mean temperature difference

Assuming cross flow type heat exchanger for absorber cooling process.

$$LMTD = \frac{(Th_i - Tc_o) - (Th_o - Tc_i)}{ln\left(\frac{Th_i - Tc_o}{Th_o - Tc_i}\right)}$$

where,
Th_i = Inlet Temperature of absorber refrigerant.
Th_o = Outlet Temperature of refrigerant from absorber.
Tc_i = Temperature of air before crossing from absorber.
Tc_o = Temperature of air after crossing from absorber.
LMTD = 7.39°C
The total external heat transfer area
A_t = 7.83 m^2
Inside area
A_i = 0.602
Length of tube
L= 8.33 m
Number of tube
n = 19.83 m
Number of row
R = 1.53
Number of tube per row
R_t = 14.87
Thickness of fins
T = 0.268 mm
Space between fins
f_s = 1.88 mm

Evaporator

The most common materials used for tubes are carbon steel, aluminum, and stainless steel for ammonia refrigerant. The most common sizes of tube for ammonia evaporator are 20 mm to 25 mm, sometime 15 mm tube is also used assuming inside and outside diameter of tube are 13 mm and 16 mm. Assuming the dimension of evaporator 230 mm width, 220 mm height, 70 mm depth.

Design calculation

Air conditioning system depends on size of car. For running air conditioning system in car 0.80 TR is needed which is equivalent to 2.8 KW. Hence the evaporator is designed to have capacity of 2.8 KW heat transfer.

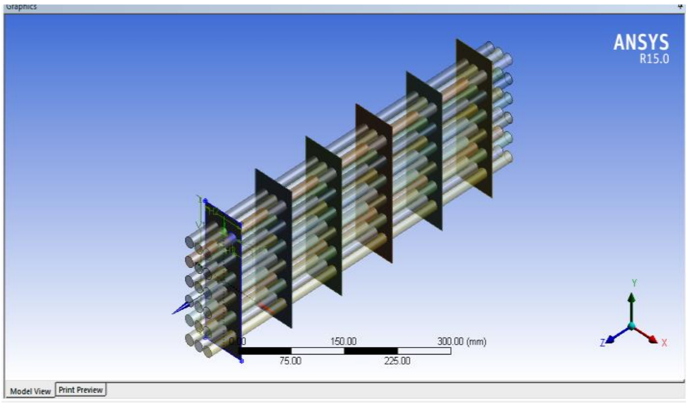

Fig. 4. Design of evaporator.

Log mean temperature difference

Assuming cross flow type heat exchanger for evaporator cooling process.

$$LMTD = \frac{(Th_i - Tc_o) - (Th_o - Tc_i)}{ln\left(\frac{Th_i - Tc_o}{Th_o - Tc_i}\right)}$$

Where,
Th_i = Temperature of air before crossing of evaporator.
Th_o = Temperature of air after crossing from evaporator.
Tc_i = Inlet temperature of refrigerant of evaporator.
Tc_o = Outlet temperature of refrigerant of evaporator.
LMTD = 8.55°C
Inside area of tube
A_i = 0.521m
Length of tube
L= 12.75 m
Number of tube
N = 55.4
Number of row
R = 3.5
Number of tube per row
R_t = 9.16
Thickness of fins
T= 0.130 mm
Spacing between fins
f_s = 1.77 m

III. Comparison of Fins and Tube

Generator

Taking, fins materials as Aluminum, Copper and Magnesium.
And Tube material as steel.

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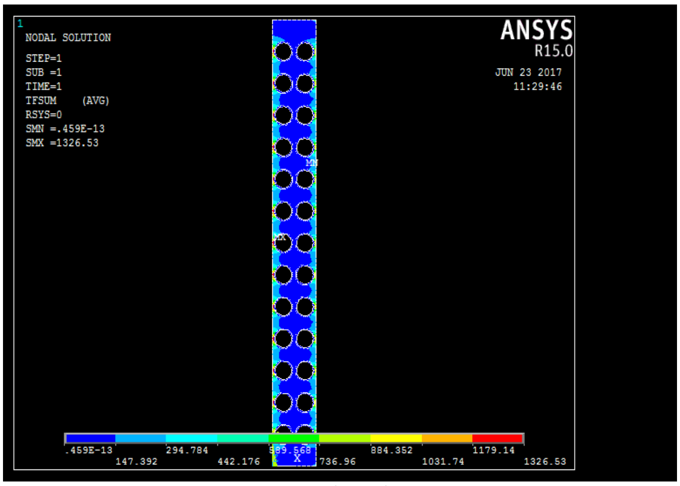

Fig. 5. Thermal flux of generator.

TABLE 1. Comparison of thermal flux of generator.

S.No	Aluminum	Copper	Magnesium
1	17466.3	33409.8	14652.2
2	15525.6	29697.6	13024.2
3	13584.9	25985.4	11396.2
4	11644.2	22273.2	9768.13
5	9703.5	18561	8140.11
6	7762.8	14848.8	6512.09
7	5822.1	11136.6	4884.07
8	3881.4	7424.4	3256.04
9	1940.7	3712.2	1628.02

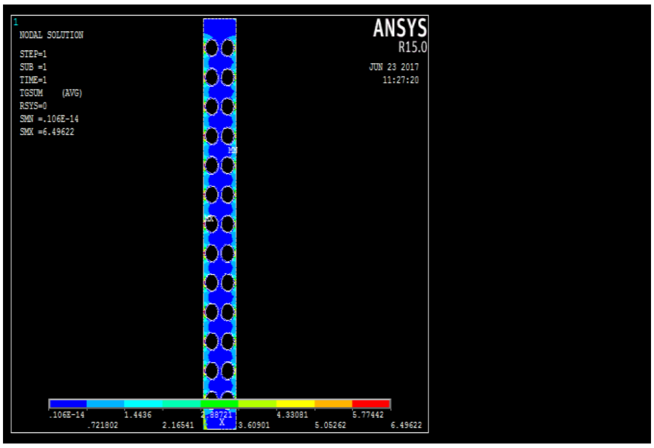

Fig. 6. Thermal gradient of generator.

TABLE 2. Comparison of thermal gradient of generator.

S. No	Aluminum	Copper	Magnesium
1	85.53	86.55	85.53
2	76.03	76.93	76.03
3	66.52	67.31	66.52
4	57.02	57.70	57.02
5	47.51	48.08	47.51
6	38.01	38.46	38.01
7	28.51	28.85	28.51
8	19.00	19.23	19.00
9	9.50	9.61	9.50

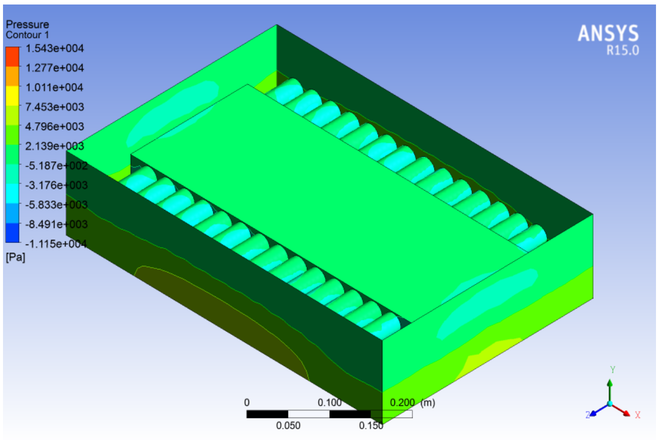

Fig. 7. Pressure generated in generator.

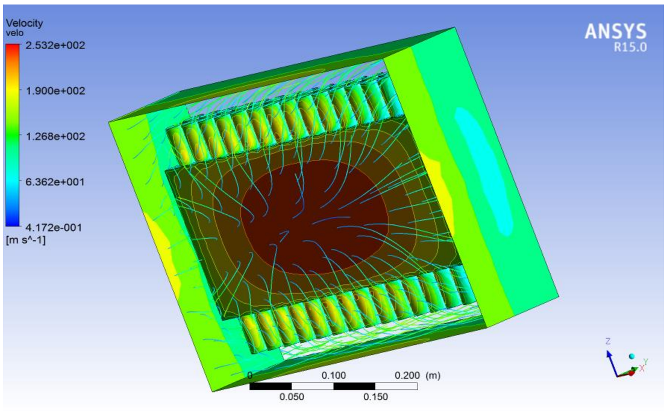

Fig. 8. Velocity generated in generator.

TABLE 3. Pressure and velocity of generator.

S. No	Pressure	Velocity
1	1.543e+004	2.532e+002
2	1.011e+004	1.900e+002
3	4.796e+003	1.268e+002
4	-5.187e+003	6.362e+001
5	-1.115e+004	4.172e-001

Condenser

Taking, fins materials as Aluminum, Copper and Magnesium.
And Tube material as steel.

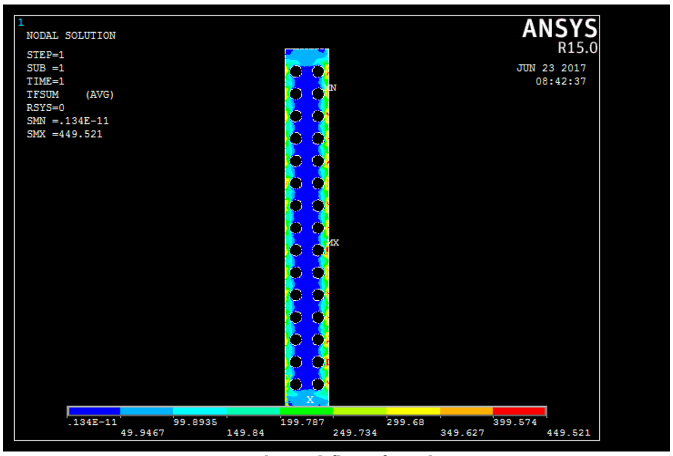

Fig. 9. Thermal flux of condenser.

TABLE 4. Comparison of thermal flux of condenser.

S. No	Aluminum	Copper	Magnesium
1	449.52	837.06	371.47
2	399.57	744.06	330.20
3	349.62	651.05	288.92
4	299.68	558.04	247.65
5	249.73	465.03	206.37
6	199.78	372.03	165.10
7	149.84	279.02	123.82
8	99.89	186.01	82.55
9	49.94	93.00	41.27

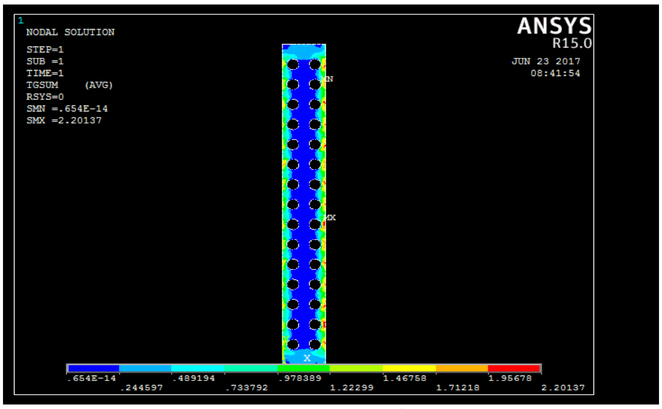

Fig. 10. Thermal gradient of condenser.

TABLE 5. Comparison of thermal gradient of condenser.

S. No	Aluminum	Copper	Magnesium
1	2.20	2.16	2.16
2	1.95	1.92	1.92
3	1.71	1.68	1.68
4	1.46	1.44	1.44
5	1.22	1.20	1.20
6	0.97	0.96	1.96
7	0.73	0.72	0.72
8	0.48	0.48	0.48
9	0.24	0.24	0.24

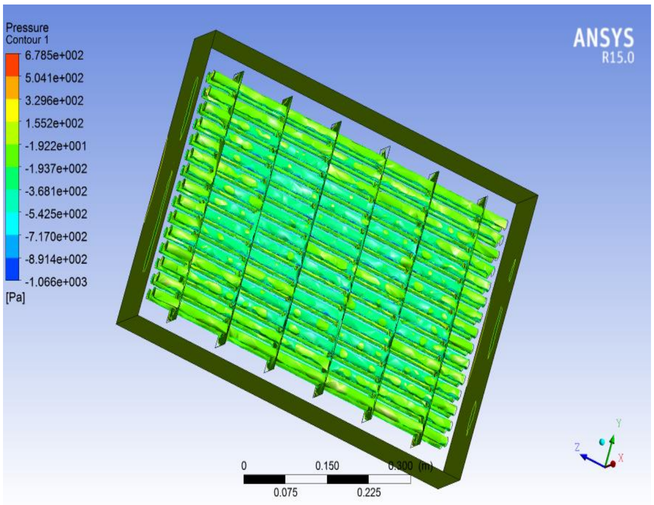

Fig. 11. Pressure generated in condenser.

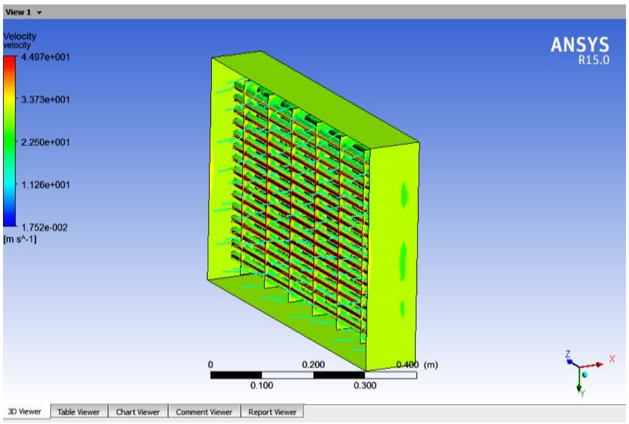

Fig. 12. Velocity generated in condenser.

TABLE 6. Pressure and velocity of condenser.

S. No	Pressure	Velocity
1	6.785e+002	4.497e+001
2	3.296e+002	3.373e+001
3	-1.922e+001	2.250e+001
4	-3.681e+002	1.126e+001
5	-1.066e+003	1.752e-002

Absorber

Taking, fins materials as Aluminum, Copper and Magnesium.

And Tube material as steel.

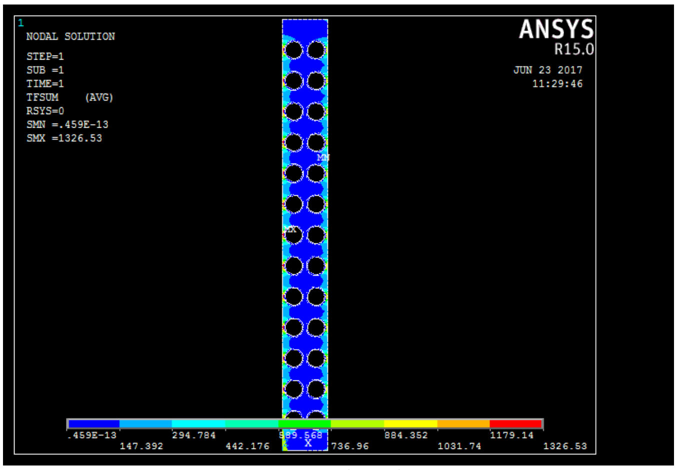

Fig. 13. Thermal flux of absorber.

TABLE 7. comparison of thermal flux of absorber

S. No	Aluminum	Copper	Magnesium
1	1326.53	2507.54	1112.8
2	1179.14	2228.93	989.15
3	1031.74	1950.31	865.51
4	884.35	1671.69	741.86
5	736.96	1393.03	618.22
6	589.56	1114.46	494.57
7	442.17	835.84	370.93
8	294.78	557.23	247.28
9	147.39	278.61	123.64

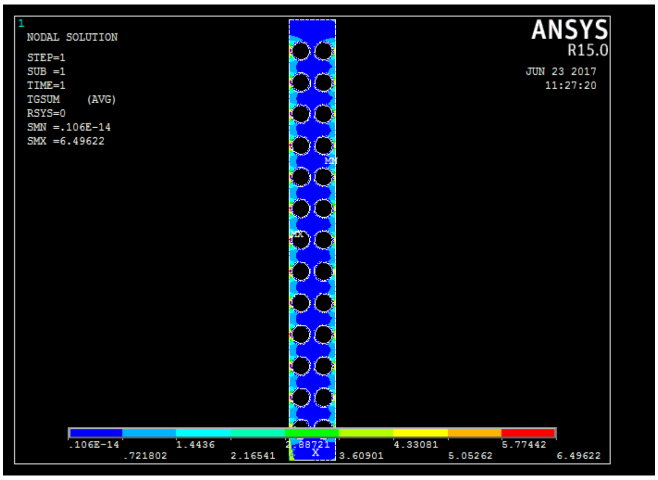

Fig. 14. Thermal gradient of absorber.

TABLE 8. Comparison of thermal gradient of absorber.

S. No	Aluminum	Copper	Magnesium
1	6.49	6.49	6.49
2	5.77	5.77	5.77
3	5.05	5.05	5.05
4	4.33	4.33	4.33
5	3.60	3.60	3.60
6	2.88	2.88	2.88
7	2.16	2.16	2.16
8	1.44	1.44	1.44
9	0.72	0.72	0.72

Pressure and Velocity of absorber

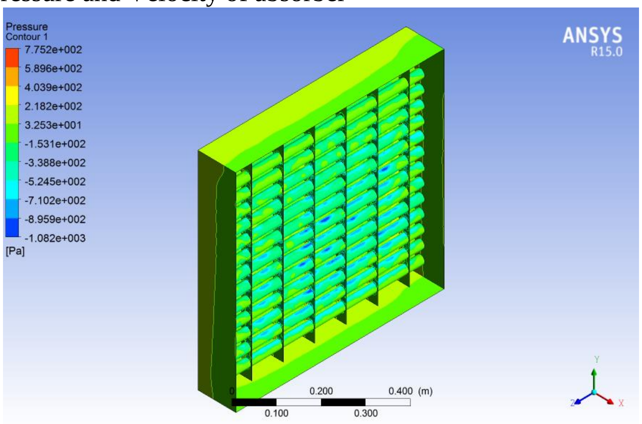

Fig. 15. Pressure generated in absorber.

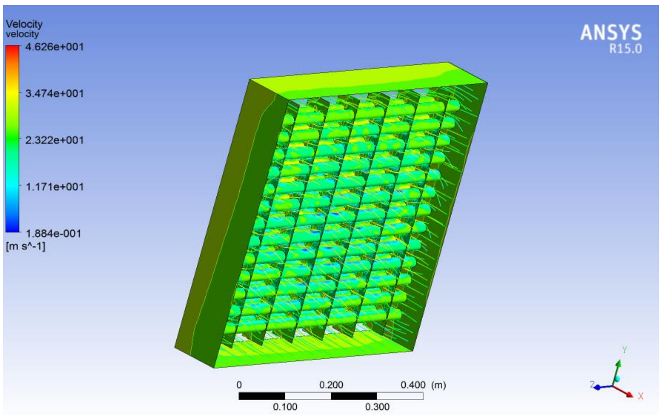

Fig. 16. Velocity generated in absorber.

TABLE 9. Pressure and velocity of absorber.

S. No	Pressure	Velocity
1	7.752e+002	4.626e+001
2	4.039e+002	3.474e+001
3	3.253e+001	2.322e+001
4	-3.388e+002	1.171e+001
5	-1.082e+003	1.884e-001

Evaporator

Taking, fins materials as Aluminum, Copper and Magnesium.
And Tube material as steel.

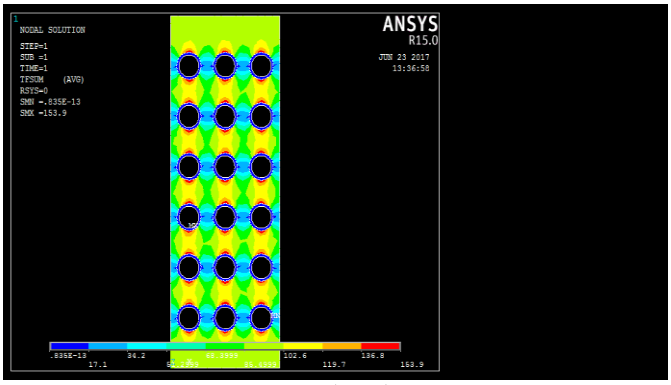

Fig. 17. Thermal flux of evaporator.

TABLE 10. Comparison of thermal flux of evaporator.

S. No	Aluminum	Copper	Magnesium
1	2284.07	153.9	68.29
2	2030.28	136.8	60.70
3	1776.5	119.7	53.12
4	1522.71	102.6	45.53
5	1268.93	85.49	37.94
6	1015.14	68.39	30.35
7	751.33	51.29	22.76
8	507.57	34.2	15.17
9	253.78	17.1	7.58

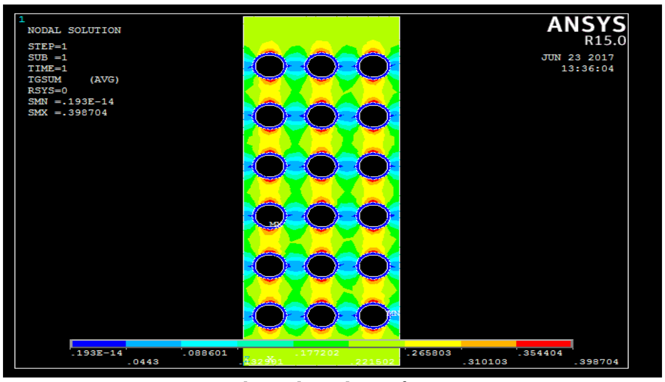

Fig. 18. Thermal Gradient of evaporator.

TABLE 11. Comparison of thermal gradient of evaporator.

S. No	Aluminum	Copper	Magnesium
1	11.21	0.39	0.39
2	9.96	0.35	0.35
3	8.72	0.31	0.31
4	7.47	0.26	0.26
5	6.22	0.22	0.22
6	4.98	0.17	0.17
7	3.73	0.13	0.13
8	2.49	0.08	0.08
9	1.24	0.04	0.04

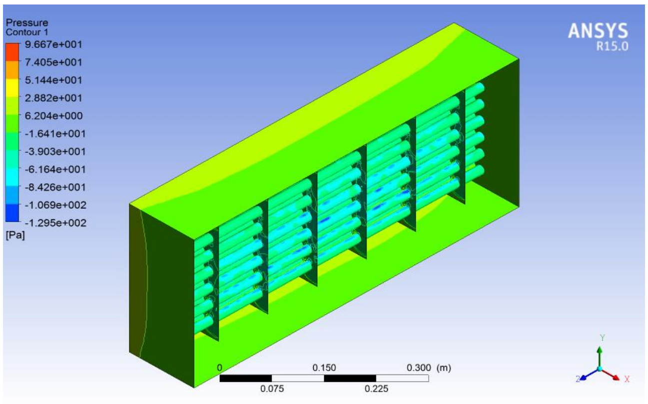

Fig. 19. Pressure generated in evaporator.

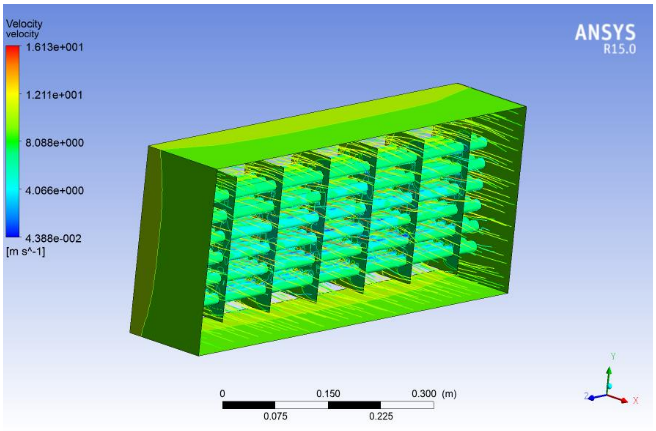

Fig. 20. Velocity generated in evaporator.

TABLE 12. Pressure and velocity of evaporator.

S. No	Pressure	Velocity
1	9.667e+001	1.613e+001
2	5.144e+001	1.211e+001
3	6.204e+000	8.088e+000
4	-3.903e-001	4.066e+000
5	-1.295e+002	4.388e-002

IV. RESULTS AND DISCUSSION

From the analysis it is seen that three materials of fins has a greater variation with the steel tubes. The data reported in the thermal flux and thermal gradient of generator it is seen that aluminum with steel tube has a greater heat transfer through surface per unit time and thermal gradient is more rapidly at the fins material coming from tubes so aluminum is good material chosen for generator as compare to magnesium and copper.

The simulation data says in the thermal flux and thermal gradient of condenser it is seen that aluminum with steel tube has a greater heat transfer through surface per unit time and thermal gradient is more rapidly at the fins material coming from tubes so aluminum is good material chosen for condenser as compare to magnesium and copper.

The simulation data says in the thermal flux and thermal gradient of absorber it is seen that aluminum with steel tube has a greater heat transfer through surface per unit time and thermal gradient is more rapidly at the fins material coming from tubes so aluminum is good material chosen for absorber as compare to magnesium and copper.

The simulation data says in the thermal flux and thermal gradient of evaporator it is seen that aluminum with steel tube has a greater heat transfer through surface per unit time and thermal gradient is more rapidly at the fins material coming from tubes so aluminum is good material chosen for evaporator as compare to magnesium and copper.

In my thesis the report says that magnesium with steel tube would be good combination for fins and tube material for the cooling and heating of the ammonia water refrigerants through vapour Absorption Refrigeration System in cars.

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