Experimental Analysis of Air Conditioner by Combination of Conventional and Non-Conventional Energy Sources

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Abstract— In the world scenario the biggest problem is always attach with energy. We are facing a large scarcity of energy and for that it will always beneficial to minimize the energy consumption. So for that this paper contain an experimental method by which we can see how much energy we can save by applying three different energy source for establishing an air conditioning system. While in three energy source one is conventional energy source and another two is non-conventional energy source. The conventional energy source is applied to simple vapor compression cycle and Peltier effect and non-conventional energy source is applied to extract energy from earth heat exchanger. This project also contains a big role of heat pipe which is used to transport energy from on point to other. This project also contains the compression of energy consumption with three different conditions which are: (1) When only vapor compression cycle is used (2) When vapor compression cycle is used with earth heat exchanger. (3) When vapor compression cycle is used with Peltier module. (4) When vapor compression cycle is used with earth heat exchanger as well as Peltier module.

Key words: Non-Conventional Energy Sources, Analysis of Air Conditioner

I. Introduction

The effect of air-conditioning demand makes the energy consumption has been increasing quickly. The investigation report shows that of the total energy consumption in buildings in Metro city, the energy amount used by air-conditioning system is 46.1% in restaurant building, 40.5% in commercial building, 49.7% in office building, and 30.3% in hospital building. The ever increasing energy requirement puts a great burden on the further economic development as India is poor in energy resources. How to reduce the energy consumption by using new energy saving technologies and equipment is an important task now days. In order to reduce the energy consumption in air-conditioning building, apparatus dew-point air supply is usually used in air-Conditioning systems. But as the moist air leaving the cooling coil is usually too high in relative humidity (about 95% Rh) and too low in temperature to be used in occupied spaces directly, people usually feel uncomfortable. Besides, if the relative humidity in occupied spaces and low-velocity ducts and plenums exceeds 70%, fungal contamination such as mold, mildew, etc., can occur and threatens public health. Therefore, from the requirement of keeping good indoor thermal comfort and air quality, and of reducing the risk of catching disease, it is a strong recommendation to keep the supply air humidity below 70%. This means that relative humidity control in the air supply is important aspect. But if conventional cooling coils are used to improve the indoor thermal comfort and air quality, external energy will be used to reheat the air stream from the apparatus dew-point to the required air supply state. To solve this problem, a Peltier Module and Earth heat Exchanger air-handling coil can be employed [1].

II. Problem Statement

In order to study the performance of combined air conditioning system and analysis of the variation of COP in different combination of vapor compression system, earth heat exchanger and Peltier Module, the experimental setup is being arranged and fabricated, along with vapor compression system. Testing and performance analysis of newly combined air conditioning system will be done at different experimental setup, and then affecting system parameters will be analyzed. Suitable manufacturing methods will be employed to fabricate the components and then assemble the test setup. The fabrication will be carried out as per layout shown below. Test & Trial on hybrid peltier air conditioner determine, temperature gradient, cooling ability (tonnage) and COP of system, under given conditions and derive performance characteristic.

III. Objective

The main objective of this investigation is to study the performance of the Hybrid Air Conditioning System. The proposed work includes the determination of heat load, to maintain 13 to 15ºC temperature in the cabinet of volume close to 5 liters.

1) Test &Trial on combined air conditioner determine temperature gradient, cooling ability (tonnage) and COP of system, under given conditions
   - Vapor Compression Air Conditioning unit and derive performance characteristic
   - Vapor Compression Air Conditioning unit with Earth heat exchanger unit and derive performance characteristic
   - Vapor Compression Air Conditioning with Peltier module unit and derive performance characteristic.
   - Vapor Compression Air Conditioning with Earth heat exchanger and Peltier module unit and derive performance characteristic.
2) Performance analysis of combined air conditioner with load under given conditions
   - Vapor Compression Air Conditioning unit and derive performance characteristic
   - Vapor Compression Air Conditioning unit with Earth heat exchanger unit and derive performance characteristic.
   - Vapor Compression Air Conditioning with Peltier module unit and derive performance characteristic.
   - Vapor Compression Air Conditioning with Earth heat exchanger and Peltier module unit and derive performance characteristic.

IV. COMPONENTS & ITS SPECIFICATION

A. Vapor Compression Cycle

Capacity (Ton	0.25
Star Rating	1
Cooling (watt)	549 WATT
Compressor	Rotary
EER (BTU / Hr./W)	0.49
Noise Level (db)	45
Cooling Function	
Temp. Control	Thermistor
Connivance function	
Operation Control	Electronic
Energy saver	Yes
Electricity Rating	
Power Supply (Volt/Phase/Hz.)	230 / Single / 50
Power Input (Watts)	200
Running Current (Amps)	4.6

Table 1: Specifications of Vapor Compression Cycle

B. Peltier Effect Refrigerate

Parameters of Category	Series-Parallel Modules
Imax	ser 1.9 par 3.7 amp(s)
Qmax	36.6 watt(s)
Vmax	ser 31.8 par 15.9 volt(s)
DT max	72 Th=300K
A	40 mm
B	40 mm
C	40 mm
D	40 mm
H	4.8 mm

Table 2: Specification of Peltier Module

C. Heat Pipe Geometry- Size Selection

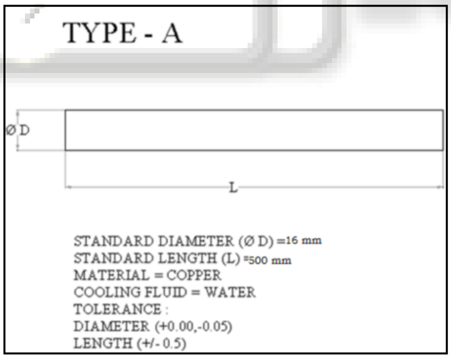

Fig. 1(a): Heat Pipe Geometry- Size Selection

V. THERMAL ANALYSIS OF SPIRAL RADIAL FINS FOR HEAT PIPE MODULE AND PELTIER MODULE

A. Thermal Analysis of Test Model-I

Thermal analysis of Spiral radial fin structures using ANSYS of Test Model Spiral radial Fins is given in that Geometry, IGES file of the model imported to ANSYS work bench 14.5 meshing is carried out using free meshed by tetrahedron elements the number of elements and nodes is given below for each fin structure. Meshing done with Nodes are 48122 and Elements are 7065 then, we applied boundary condition to Spiral radial fin of all four test models like Convection at 35W/m2°C and Temperature at 21°C which is given in following diagrams, finally thermal analysis for finding different parameters like Total Heat Flux, Directional heat flux in x-direction and Temperature gradient as shown in figure.

1) Geometry

Geometry of Test Model-I of Spiral radial fins is done in ANSYS of work bench 14.5 which is presented in Fig. 1

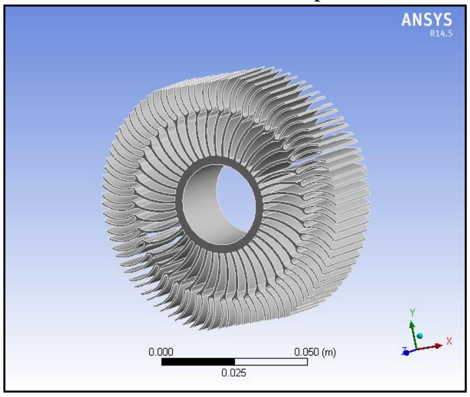

Fig. 1: Geometry of Test Model-I in ANSYS

2) Applying Boundary Conditions

Now, we applied the boundary conditions to the given Spiral radial fin structure convection at 35W/m2°C and Temperature at 21°C which is shown in Fig. 2

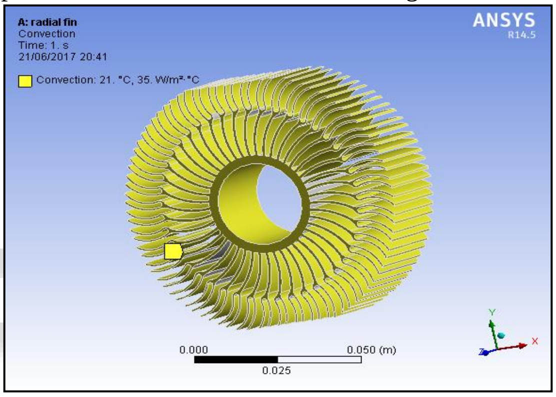

Fig. 2 Boundary Condition at 21°C

3) Temperature at 32°C

Boundary condition temperature at 32°C of Test Model of Spiral radial Fins is shown in Fig. 3.

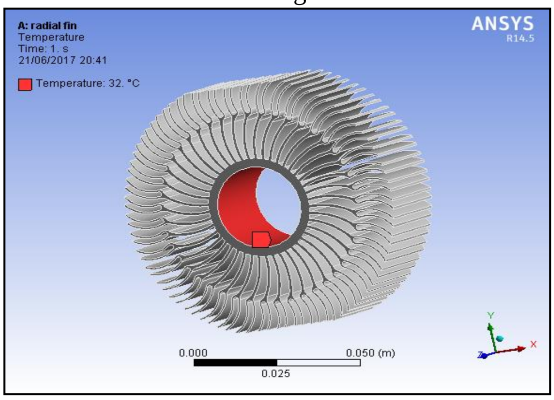

Fig. 3 Boundary Condition at 32°C

4) Analysis Results

Now, after applying the boundary condition we find the analysis results with following points like maximum Total Heat Flux at 20310W/m2, maximum Directional heat Flux in x-direction at 20255 W/m2 and Maximum Temperature Gradient at 32C.

5) Total Heat Flux

Figure 4 shows Maximum Total Heat Flux at 20310 W/m^2

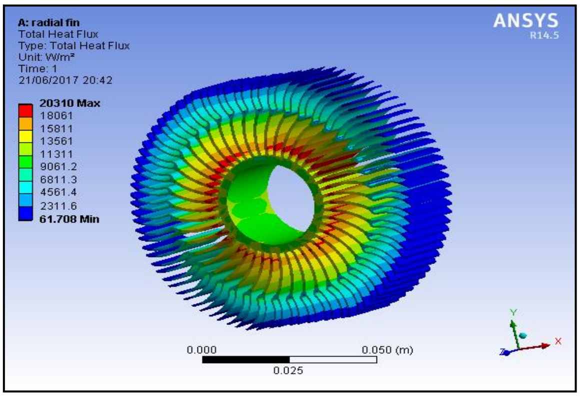

Fig. 4: Total Heat Flux of Test Model-I

6) Directional Heat Flux in x-Direction

Figure 5 shows maximum Directional heat Flux in x-direction at 20192 W/m^2

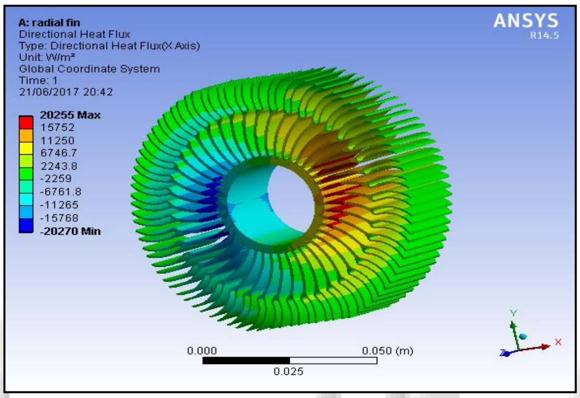

Fig. 5: Directional heat Flux in x-direction of Test Model-I

7) Temperature Gradient

Figure 6 shows maximum temperature Gradient at 32C.

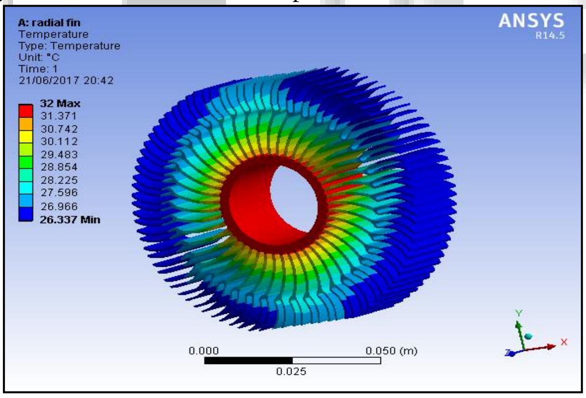

Fig. 6: Temperature gradient of Test Model-I

B. Thermal Analysis of Test Model-II

Thermal analysis of Spiral fin structures using ANSYS of Test Model Spiral fin is given in that Geometry, IGES file of the model imported to ANSYS work bench 14.5 meshing is carried out using free meshed by tetrahedron elements the number of elements and nodes is given below for each fin structure. Meshing done with Nodes are 48122 and Elements are 7065 then, we applied boundary condition to Spiral fin of all four test models like Convection at 46 W/m2°C and Temperature at 28°C which is given in following diagrams, finally thermal analysis for finding different parameters like Total Heat Flux, Directional heat flux in x-direction and Temperature gradient as shown in figure.

1) Geometry

Geometry of Test Model-II of Spiral fin is done in ANSYS of work bench 14.5 which is shown in Fig. No 7

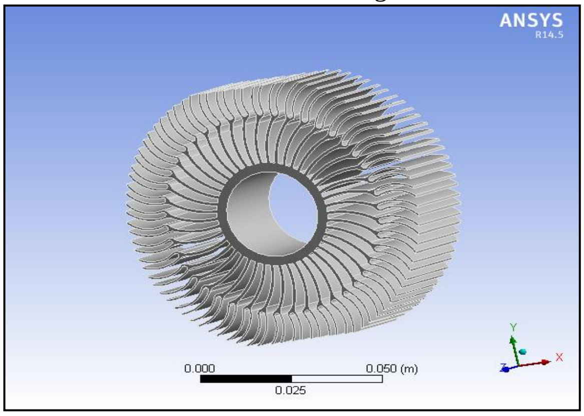

Fig. 7: Geometry of Test Model-II

2) Applying Boundary Conditions

Now, we applied the boundary conditions to the given Spiral fin structure convection at 46 W/m^2°C and Temperature at 28°C which is shown in Fig. 8.

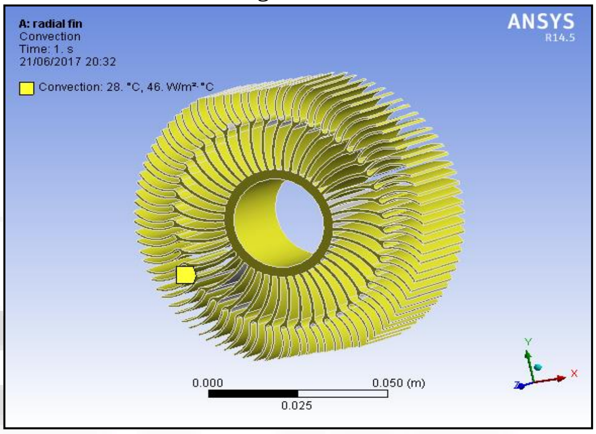

Fig. 8: Boundary Condition Temperature at 28°C

3) Temperature at 80°C

Fig no.9 shows the Boundary condition temperature at 80°C of Test Model of Spiral Fins

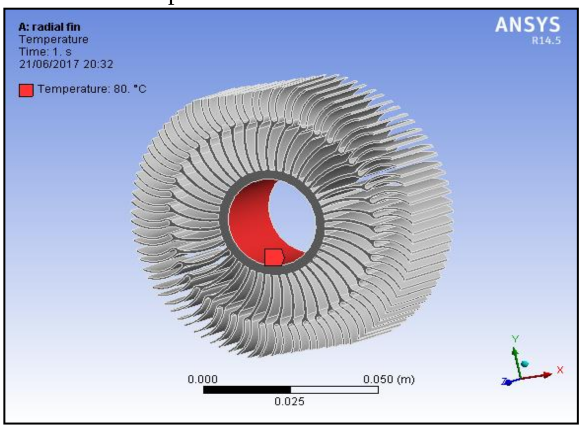

Fig. 9: Boundary Condition Temperature at 80°C

4) Analysis Results

Now, after applying the boundary condition we find the analysis results with following points like maximum Total Heat Flux at 112420 W/m^2, maximum Directional heat Flux in x-direction at 112140 W/m^2 and Maximum Temperature Gradient at 80C.

5) Total Heat Flux

Figure 10 shows Maximum Total Heat Flux at 112420 W/m^2

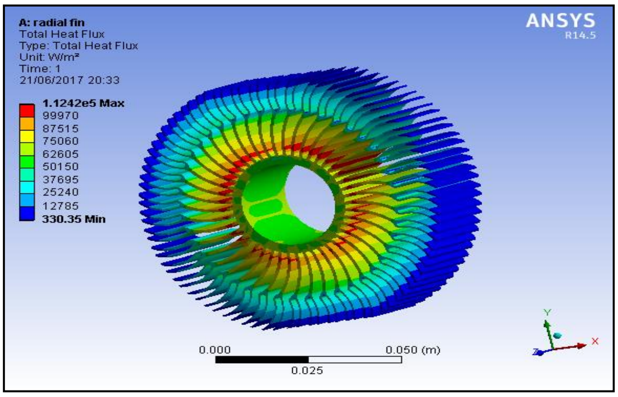

Fig. 10: Total Heat Flux of Test Model-II

6) *Directional Heat Flux in x-Direction*

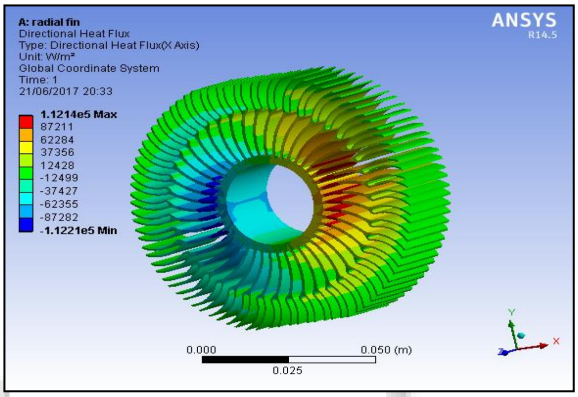

Fig. 11: Shows maximum Directional heat Flux in x-direction at 112140 W/m^2

Fig. 11 Directional heat Flux in x-direction of Test Model-II

7) *Temperature Gradient*

Figure 12 shows maximum temperature Gradient at 80C.

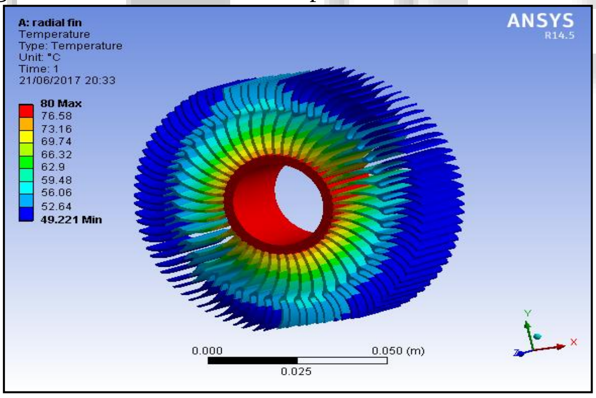

Fig. 12: Temperature gradient of Test Model-II

VI. EXPERIMENTATION

A. *Test & Trial-I on Conventional VC-Model*

1) *Procedure*

– Start compressor
– Peltier module off
– Earth heat exchanger off
– Take temperature readings after every 3min

No	Time	Mass of air	T1	T2	ΔT	Compressor Power	Net comp. power
1	3	10.4	30	27	3	93	93
2	6	10.4	31	25	6	91	91
3	9	10.4	31	23	8	86	86
4	12	10.4	30	21	9	85	85
5	15	10.4	31	20	11	83	83

Table 3: Observation Table for trial-I

2) *Calculation*

– KWH= (time/60) X (compression power)/1000
– COP= (mcpΔt / 3600) /(KWH)
– Tonnage=COP/3.517

3) *Result table*

No	Time	ΔT	Net Comp. Power	mcp Δt	COP
1	3	3	93	31.3248	0.62375149
2	6	6	91	62.6496	0.9457971
3	9	8	86	83.5328	1.27492063
4	12	9	85	93.9744	1.14062422
5	15	11	83	114.8576	1.53758501

Table 4: Result Table for trial-I

B. *Test & Trial-I on Conventional Vc-Model with Earth Heat Exchanger*

1) *Procedure*

– Start compressor
– Peltier module off
– Earth heat exchanger
– Take temperature readings after every 3min

No	Time	Mass of air	T1	T2	ΔT	Compressor Power	Net compressor power
1	3	10.4	30	28	2	91	91
2	6	10.4	31	24	7	89	89
3	9	10.4	31	22	9	83	83
4	12	10.4	30	19	11	82	82
5	15	10.4	31	16	15	80	80

Table 5: Observation Table for trial-II

2) *Calculation*

– KWH= (time/60) X (compression power)/1000
– COP= (KWH)/((mcpΔt)*3600)
– Tonnage=COP/3.516

3) *Result table*

No	ΔT	Net Compressor Power	Mcp Δt	Cop	Tonnage
1	2	91	20.8832	1.274921	0.3285878
2	7	89	73.0912	2.281248	0.5879506
3	9	83	93.9744	2.096707	0.5403884
4	11	82	114.8576	1.94542	0.5013969
5	15	80	156.624	2.175333	0.5606529

Table 6: Result Table for trial-II

C. Test & Trial-II on conventional VC-model with Peltier module

1) Procedure

- Start compressor
- Peltier module on
- No earth heat exchanger
- Take temperature readings after every 3min

No	Time	Mass of air	T1	T2	ΔT	Compressor Power	P.M. Power	Net compressor power
1	3	10.4	30	28	2	91	21	112
2	6	10.4	31	24	7	88	18	106
3	9	10.4	31	21	10	83	15	98
4	12	10.4	30	17	13	80	12	92
5	15	10.4	31	13	18	77	11	88

Table 7: Observation Table for trial-III

2) Calculation

- KWH= (time/60) X (compression power)/1000
- COP= (KWH)/((mcpΔt)*3600)
- Tonnage=COP/3.516

3) Result Table

No	ΔT	Net Compressor Power	mcp Δt	Cop	Tonnage
1	2	112	20.8832	1.035873	0.2669776
2	7	106	73.0912	1.915388	0.4936567
3	10	98	104.416	1.973091	0.5085287
4	13	92	135.7408	2.049227	0.5281513
5	18	88	187.9488	2.373091	0.6116214

Table 8: Result Table for trial-III

D. Test & Trial-III on Conventional VC-Model with Peltier Module and Earth Heat Exchanger

1) Procedure

- Start compressor
- Peltier module on
- Earth Heat Exchanger
- Take temperature readings after every 3min

No	Time	Mass of Air	T1	T2	ΔT	Compressor Power	Peltier Module Power	Net Compressor Power
1	3	10.4	30	28	2	88	15	103
2	6	10.4	31	24	7	82	15	97
3	9	10.4	31	19	12	76	13	89
4	12	10.4	30	15	15	71	12	83
5	15	10.4	31	11	20	70	11	81

Table 9: Observation Table for trial-IV

2) Calculation

- KWH= (time/60) X (compression power)/1000
- COP= (KWH)/((mcpΔt)*3600)
- Tonnage=COP/3.516

3) Result table

No	ΔT	Net Compressor Power	mcp Δt	Cop	Tonnage
1	2	103	20.8832	1.126386	0.2903057
2	7	97	73.0912	2.093104	0.5394599
3	12	89	125.2992	2.607141	0.6719436
4	15	83	156.624	2.620884	0.6754854
5	20	81	208.832	2.864636	0.7383084

Table 10: Result Table for trial-IV

VII. GRAPHICAL RESULT

A. Graph Result-1

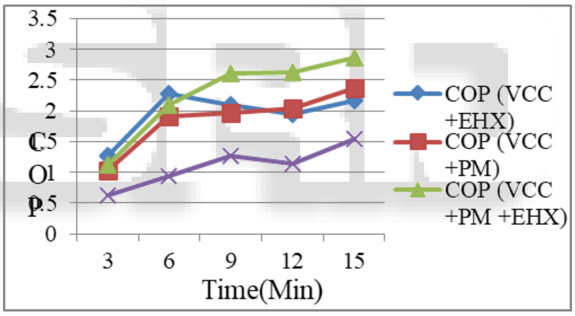

Fig. 13: Comparison of COP

1) Result

- COP of (VCC+PM+HEX) is maximum and thus most effective of the three combinations hence it is recommended that all three modifications of the Combined system be used for best results.
- Comparison of the COP of (VCC+ PM) & (VCC +EHX) shows that (VCC +PM) shows better COP as compared to the (VCC +EHX)over delayed duty cycle ie, from 12 to 15min , hence will be recommended if the temperature cycling is to done over a range above 12minutes time.
- Comparison of the COP of (VCC+ PM) & (VCC +EHX) shows that (VCC +EHX) shows better COP as compared to the (VCC +PM)over short duty cycle ie, from 0 to 12min , hence will be recommended if the temperature cycling is to done over a range below 12minutes time.
- COP of single VCC is minimum.

2) Discussion on Result- 1

- Graph Result-I give us COP in VCC and Comparison of COP for three distinct case and these cases are "Result from trail –II, Result from trail-III and Result from Trail –IV". As we have three distinct table so this graphical result help us to study the optimized condition.

- Graph result-I also shows that up to certain time i.e. 6 minute the performance of (VCC +EHX) has better. Reason behind it for that is upto 6 min peltier module doesn't have effective cooling capacity in comparison of earth heat exchanger.
- This result shows that trail – III have higher COP and it will be most appropriate condition which is because that in trail test III we take three different energy source instead of two sources.
- COP of single VCC is minimum as compare to result 1,2 & 3.

B. *Graph Result 2*

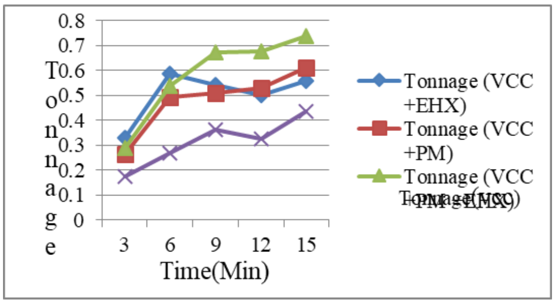

Fig. 14: Comparison of Tonnage

1) *Result*

- Tonnage of (VCC+PM+HEX) is maximum and thus most effective of the three combinations hence it is recommended that all three modifications of the hybrid system be used for best results.
- Comparison of the Tonnage of (VCC+ PM) & (VCC +EHX) shows that (VCC +EHX) shows better Tonnage as compared to the (VCC +PM)over short duty cycle ie, from 0 to 12min, hence will be recommended if the temperature cycling is to done over a range below 12minutes time.
- Comparison of the Tonnage of (VCC+ PM) & (VCC +EHX) shows that (VCC +PM) shows better Tonnage as compared to the (VCC +EHX)over delayed duty cycle i.e., from 12 to 15min, hence will be recommended if the temperature cycling is to done over a range above 12minutes time.
- Tonnage in single VCC is low

2) *Discussion on Result- II*

- Graph Result-II give us comparison of tonnage for three distinct case and these cases are "Result from trail –I, Result from trail-II and Result from Trail –III". As we have three distinct table so this graphical result help us to study the optimized condition.
- This result shows that trail – III have higher tonnage and it will be most appropriate condition which is because that in trail test III we take three different energy source instead of two sources.
- Graph result-II also shows that up to certain time i.e. 6 minute the tonnage of (VCC+EHX) has better. Reason behind it for that is upto 6 min peltier module doesn't have effective cooling capacity in comparison of earth heat exchanger.
- Tonnage in single VCC is low as compared to result 1, 2 & 3.

C. *Graph Result-3*

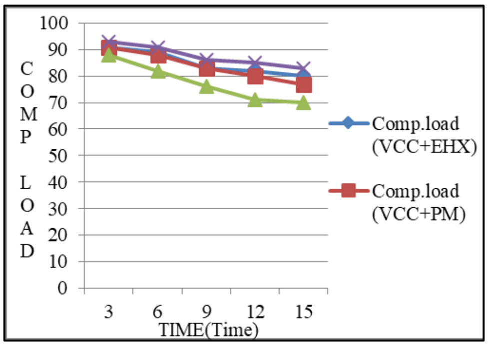

Fig. 15: Comparison of Comp. Load

D. *Result*

1) Comp. load for (VCC+PM+HEX) is minimum and thus most effective of the three combinations hence it is recommended that all three modifications of the Combined system be used for best results.
2) Comparison of the Comp. load for (VCC+ PM) & (VCC +EHX) shows that (VCC +EHX) required more Comp. load as compared to the (VCC +PM)over short duty cycle ie, from 9 to 12min .
3) Comparison of the Comp. load for (VCC+ PM) & (VCC +EHX) shows that (VCC +PM) required low Comp. load as compared to the (VCC +EHX) over short duty cycle ie, from 9 to 12min .
4) Comp. load for single VCC is higher as compared to result 1,2 & 3.

VIII. CONCLUSION

1) Cop of the hybrid system increases with application of the Peltier module and Earth heat exchanger arrangement to up to 34%
2) Tonnage of the hybrid system increases with application of the Peltier module and Earth heat exchanger arrangement to up to 35 %
3) Comp. load for combined system increases with application of the Peltier module and Earth heat exchanger arrangement to up to 1.20 %
4) Thermodynamically work done on entire system is decreased due to increase in Cop.

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