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PERFORMANCE ANALYSIS OF VAPOUR COMPRESSION THERMOELECTRIC REFRIGERATION SYSTEM WITH NOZZLE AND DIFFUSER THROUGH INCORPORATION OF PHASE CHANGE MATERIAL

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Abstract— ***Refrigerator has become an essential commodity rather than luxury item. It is one of the home appliance utilizing vapor compression cycle in it process. Performance of this system becomes main issue and many researches are still ongoing to evaluate and improve efficiency of the system. The impact of ongoing science and technology has created a variety of systems that can be used in producing refrigeration effect with the use of Thermoelectric module which produces energy which can be further used in generation of cooling or heating effect.***

This study evaluates the influence of latent heat storage elements on the condenser temperature of a commercial household refrigerator. A standard wire and tube condenser is equipped with different heat storage elements and peltier module is placed at the evaporator. Phase change materials are used to reduce the condenser temperature as they are used to store latent heat. Peltier module increases the suction temperature of the evaporator. Nozzle is incorporated at the evaporator inlet and Diffuser at condenser inlet. Performance of this system will be analysed and cop will be estimated.

Keywords—Latent heat storage, peltier module, phase change materials, Nozzle, Diffuser

INTRODUCTION

Vapor compression refrigeration system is giving its best performance but the only challenge being faced is the usage of refrigerants like chlorofluorocarbons and hydrocarbons which are harmful to the environment as well as for human lives. Thus Thermoelectric refrigeration can be used as a best substitute for vapor compression refrigeration system. Thermoelectric refrigeration is a pretty development in the field of refrigeration. Latent heat storage is relatively a new area for research phase change materials are latent heat storage elements. As the source temperature rises, the chemical bonds within the PCM break up as the material changes phase from solid to liquid. The phase change is a heat seeking process that is an endothermic process and thus phase change material absorbs heat upon storing heat in the storage material, the material begins to melt when the phase change temperature is reached. Then the temperature stays constant until the melting process is finished. The heat stored during the phase change process of the material is called latent heat. Latent heat storage is more attractive than sensible heat storage because of its high storage density with smaller temperature swing. when compared latent heat storage has 5 to 10 times higher densities than sensible heat storage. Latent heat storage has 2 main advantages they are

A) It is possible to store large amounts of heat with only small temperature changes and therefore to have high storage density.

B) Due to phase change at constant temperature takes some time to complete, it becomes possible for smoothing the temperature variations.

Latent heat storages can be in a wide temperature range. Latent heat storage system using phase change materials as the most effective way of storing thermal energy. These phase change materials has the advantage of high storage density and the isothermal nature of storage process. The most commonly used phase change material is water.

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LITERATURE REVIEW

A lot of research work is being carried out about the latent heat storage elements as well as thermoelectric modules. The following literature review looks into the previous research works

Pradip subramaniam and Chetan Tulapurkar [1] Performed an experiment upon a domestic refrigerator by encapsulating the phase change materials. These phase change materials are used as thermal storage units. The main objective of this experiment was to improve the coefficient of performance and to reduce the running time of the compressor. The phase change material based refrigerator in comparison with the conventional refrigerator was found to be very effective in bringing down fluctuations in the fresh food temperature.

Boussinesq [2] conducted the experiments to reduce the electrical consumption of refrigerator system with the usage of phase change material with the usage of phase change material. With the usage of computational fluid dynamics, the actual simulations of the air flow inside the refrigerator were determined for both horizontal and vertical placement of phase change material. The computational fluid dynamics model predicted the air flow and temperature distribution within the refrigerator. The horizontally placed phase change material was found to be more effective than the vertically placed phase change material. Computational fluid dynamics predicted values as well as the experimental values are found to be in close agreement with each other.

OBJECTIVES

The main objectives of the present work is

1) To fabricate the domestic refrigerator with Pelteir module at the evaporator to avoid wet particles entering to the compressor and with phase change material OM 32 at the condenser. The set up is fabricated with nozzle at evaporator inlet and diffuser at condenser inlet.
2) To compare the coefficient of performance of the system with nozzle and diffuser without phase change material and peltier module and with phase change material and peltier module.

EXPERIMENTAL SET UP

The experimental set up comprises of a domestic refrigerator, pressure gauges, thermoelectric module, phase change material ,diffuser, nozzle. The domestic refrigerator is fabricated by installing the pressure gauges and thermocouples at the entry and exit of the refrigerant components. Then the peltier module is placed at the evaporator to prevent the entry of wet particles into the compressor. The diffuser is arranged at the condenser inlet and nozzle at the evaporator inlet and phase change material namely OM 32 is encapsulated at the condenser with the help of a thin aluminium sheet. There is no separate need of charging this material because natural available energy could be used for charging this. Further this saves energy consumption as well as reduces carbon dioxide emissions.

Fig 1 Experimental set up

Fig 2 Peltier module at the evaporator

Fig 3 pcm encapsulation at the condenser

COMPONENT SPECIFICATIONS

A. Refrigerator capacity -250 litres

B. Compressor

Reciprocating type
-Hermitically sealed
-1/8 HP,230 VOLT,50Hz

C. Refrigerant-R134a

D. Thermoelectric module

-Imax-9 amp
-Vmax-12 volts

E. Phase change material-OM 32

DATA COLLECTION

All the components are installed with thermocouples and pressure gauges and readings are noted

A. Diffuser without PCM and Peltier module

Evaporator temp. T_e	Compressor inlet temp. T_1	Diffuser outlet temp. T_2	Compressor inlet pressure P_1	Diffuser outlet pressure P_2	Time (min)
15	29.5	39.5	1.2	14	08:01
10	30	40	1.1	14.5	09:50
5	30.2	41.2	1.2	15.1	13:50
0	30.5	41.5	1.1	15.2	15:20
-3	30.2	42.5	1	15.4	15:40
-5	30.4	42.5	1	15.1	15:10

B. Diffuser with PCM and peltier module

Evaporator temp. T_e	Compressor inlet temp. T_1	Compressor Outlet temp. T_2	Diffuser outlet temp. T	Compressor inlet pressure P_1	Compressor outlet pressure P_2	Diffuser pressure P	Time(min)
15	31.2	39.2	39.6	1.4	13.9	14.3	7.5
10	31.2	39.6	40.4	1.1	14.4	14.8	8.6
5	30.9	40.4	41.6	1.2	14.6	15.4	12.4
0	30.7	41.2	41.3	1.2	15.1	15.6	14.8
-3	30.4	42.6	42.5	1	14.9	15.9	15.6
-5	30.3	43.1	43.9	0.98	15.1	16.2	22.4

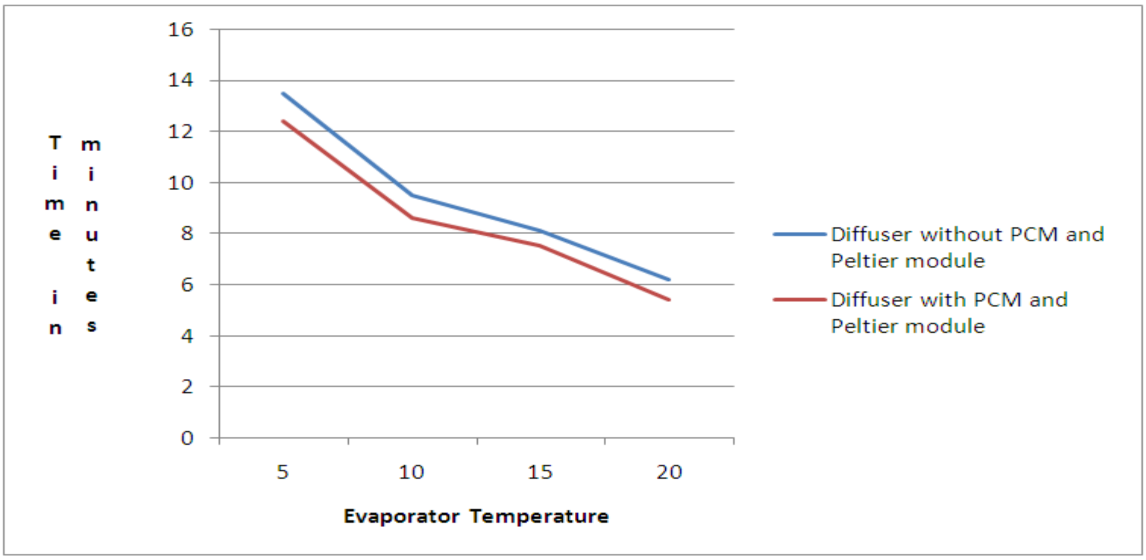
C. Nozzle without PCM and Peltier module

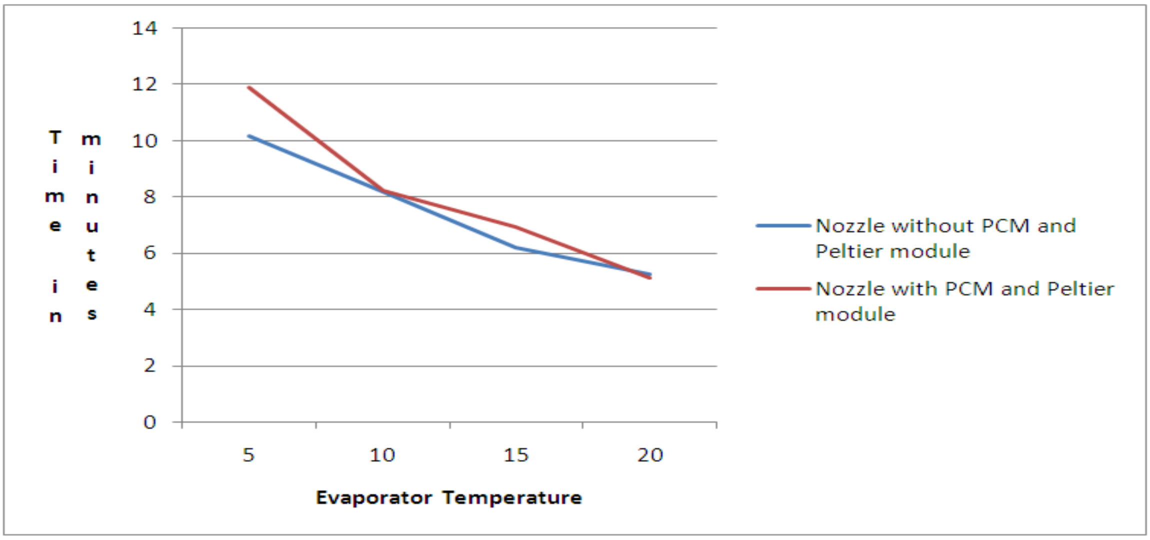
Evaporator temperature T_e	Compressor inlet temp. T_1	Nozzle outlet temp. T_2	Nozzle outlet pressure P_2	compressor outlet pressure P_1	Time (min)
15	35	19.5	1.3	13.5	6.20
10	34.3	19.2	1.4	13.9	8.16
5	34.5	18.5	1.2	14.4	10.16
0	33.9	18	1.1	14.3	12.20
-3	33.4	17.5	1.2	14.8	16.2
-5	33.4	15	1.1	15	22.4

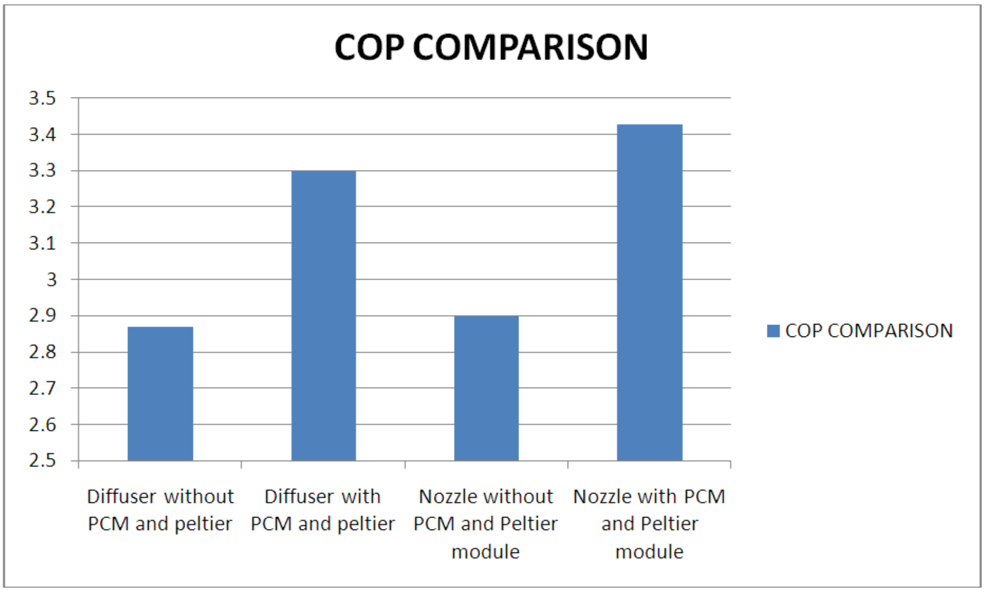
D. Nozzle with PCM and Peltier module

Evaporator temperature T_e	Compressor inlet temp.T_1	Compressor outlet tem. T_2	Nozzle outlet temp. T	Compressor inlet pressure P_1	Compressor outlet pressure P_2	Nozzle outlet pressure P	Time (min)
15	34.1	42.5	19.4	1.2	13.7	1.3	6.9
10	33.9	43.8	18.9	1.2	14.2	1.2	8.2
5	33.8	44.1	18.5	1.3	14.4	1.4	11.9
0	33.5	45.2	17.8	1.2	14.8	1.4	13.5
-2	33.7	45.7	17.3	1.1	15.2	1.3	14.9
-3	33.8	45.8	15.8	0.98	15.7	1.2	16.4
-5	33.7	46.5	14.6	0.98	15.4	1.2	21.3

GRAPHS







CALCULATIONS

A. Using diffuser without PCM and Peltier module

By taking the readings of the evaporator temperature at 0^0c and using the p-h chart of R134a we have the following values

h_1=435kJ/kg

h_2=498kJ/kg

h_3=h_4=254kJ/kg

Refrigeration effect(R.E)=h_1-h_3

= 435-254

=181

Work done(W.D)=h_2-h_1

=498-435

=63kJ/kg

Mass of refrigerant(M.R)=140000/R.E

=14000/181

=77.34kg/hr tonne

COP=R.E/W.D

=181/63

=2.87

Power consumption=(M.R*W.D)/3600

=(77.3*63)/3600

=1.35kw/tonne

B. using diffuser with PCM and peltier module

h_1=435kJ/kg

h_2=494kJ/kg

h_3=h_4=240kJ/kg

Refrigeration effect(R.E)=h_1-h_3

= 435-240

=195

Work done(W.D)=h_2-h_1

=494-435

=59kJ/kg

Mass of refrigerant(M.R)=140000/R.E

=14000/195

=71.79kg/hr tonne

COP=R.E/W.D

=195/59

=3.3

Power consumption=(M.R*W.D)/3600

=(71.79*59)/3600

=1.1765kw/tonne

C. with nozzle without PCM and Peltier module

h_1=435kJ/kg
h_2=498kJ/kg
$h_3=h_4$=252kJ/kg
Refrigeration effect(R.E)=h_1-h_3
= 435-252
=183
Work done(W.D)=h_2-h_1
=498-435
=63kJ/kg
Mass of refrigerant(M.R)=140000/R.E
=14000/183
=76.50kg/hr tonne
COP=R.E/W.D
=183/63
=2.9
Power consumption=(M.R*W.D)/3600
=(76.5*63)/3600
=1.338kw/tonne

D. using nozzle with PCM and Peltier module

h_1=437kJ/kg
h_2=493kJ/kg
$h_3=h_4$=245kJ/kg
Refrigeration effect(R.E)=h_1-h_3
= 437-245
=192
Work done(W.D)=h_2-h_1
=493-437
=56kJ/kg
Mass of refrigerant(M.R)=140000/R.E
=14000/192
=72.91kg/hr tonne
COP=R.E/W.D
=192/56
=3.42
Power consumption=(M.R*W.D)/3600
=(72.91*56)/3600
=1.134kw/tonne

RESULTS

S.NO	PARAMETERS	WITHOUT PCM AND PELTIER FOR DIFFUSER	WITH PCM AND PELTIER FOR DIFFUSER	WITHOUT PCM AND PELTIER FOR NOZZLE	WITH PCM AND PELTIER FOR NOZZLE
1	Refrigerating effect(kJ/kg)	181	195	183	192
2	Work done (kJ/kg)	63	59	63	56
3	C.O.P	2.87	3.3	2.9	3.428
4.	Power consumption(kw/tonne)	1.35	1.17	1.33	1.13
5	Refrigerant mass(kg/hr.tonne)	77.34	71.79	76.50	72.91

CONCLUSION

- From the results we can understand that as the refrigeration effect is increasing, there is a reduction in work done as well as increase in C.O.P
- After incorporating PCM and Peltier module there was a reduction in work done, increase in refrigerating effect, increase in C.O.P and decrease in power consumption
- There was about 15% increase in C.O.P for diffuser with and without PCM and Peltier module and 18% increase for nozzle with and without PCM and Peltier module
- There was about 13.3%reduction in power consumption for diffuser with and without PCM and Peltier module and for nozzle is about 15% reduction

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