Performance Measurement of Window Air Conditioner by Introducing Thermoelectric Module

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Abstract—In current scenario, energy crisis is the bottleneck for the growth of the nation. To meet the requirement of electricity, there are two ways either generation of more electricity or saving electricity. Here saving in electrical energy option has been adopted for the window air-conditioner (window air conditioning system) which can be possible by increasing the C.O.P. either by sub-cooling or superheating effect. In the present work, performance of window air conditioner has been measured without thermoelectric modules (TEM), by introducing single TEM and Two TEM which. TEM works on Peltier effect, which provides sub-cooling and superheating effect in window air conditioning system. The comparative study of obtained results was carried out for the window air conditioning system without TEM, with single TEM and with double TEM.

Key words: Energy crisis, Thermoelectric Module, Air conditioning

I. INTRODUCTION

Window air-conditioner is a common household appliance which consists of two units, inside unit and outside unit as shown in figure-1. Inside unit consists of heat exchanger/evaporator which absorbs heat from the confined place to be cool and a blower which blows cool air and maintains the air flow or motion in the place to be cooled. Outside unit consists of compressor, heat exchanger/condenser and a fan. Basically, window air conditioning system consists of four basic components: Compressor, Condenser, Expansion device (Capillary) and Evaporator. Window air conditioner works on vapour compression refrigeration (VCR) cycle as shown in figure-2.

Fig. 1: Window Air conditioning system

Fig. 2: T-S diagram of Vapour compression cycle

Fig. 3: Simple VCRS cycle
II. EFFECT OF SUPERHEATING AND SUB-COOLING

If the temperature of refrigerant leaving from the condenser coil is decreased by means of some external heat exchanger device which leads to add some cooling effect to refrigerant without changing the compressor work. This additional cooling process of refrigerant is called sub-cooling.

III. THERMOELECTRIC MODULE

Thermoelectric module is also known as thermoelectric cooler or Peltier cooler. Thermoelectric module consists of number of alternate p-type and n-type doped semiconductor thermo-elements, which is connected electrically in series and thermally in parallel. Thermo-electric elements are mounted between two ceramic substances. Thermo-electric module consists of regular matrix of thermo-electric elements (pellets), ceramic plates. The plates provide the mechanical integrity of a thermo-electric module. They must satisfy strict requirements of electrical insulation from an object to be cooled and the heat sink.

IV. THEORY FOR ANALYSIS

When DC voltage is applied to thermo-electric module, the positive and negative charges carries in the pallets array absorb heat energy from one substrate surface and release it to the opposite substrate surface. The surface from heat is absorbed becomes cold and the surface from heat is released, becomes hot. For heating and cooling purpose, thermo-electric technology is used in small laser diode coolers, portable refrigerators, scientific thermal conditioning, liquid coolers and beyond.
Refrigeration effect (R) = heat at ‘a’ – heat at ‘d’
= area ‘aejia’ – area ‘dejhd’
= area ‘adhia’/area ‘abcea’

C.O.P = R/W = area ‘adhia’/area ‘abcea’

V. EXPERIMENTAL SETUP

Fig. 7: Layout of experimental setup showing TEM

Fig. 8: Experimental Set-Up

VI. COMPONENT SPECIFICATION

1) Refrigeration capacity of window air conditioning system: 1.5 TR
2) Compressor: Reciprocating type, Hermitically sealed, 1/4 HP, 230 V, 50 Hz, A.C. only 1.1 Amp. Max.
3) Refrigerant: R22 (CHClF₂)
4) Thermoelectric Module:
   MODEL TEC1-12706
   I_max = 9 amp, V_max = 12 volts, Power = 72 watts, ΔT_max = 64°C,
5) Number of thermocouple = 127, Dimensions = 40mm*40mm*3.4mm
6) Copper Plates:
   Dimensions = 300 mm *300 mm*1 mm
7) Battery:
   3 V, 6 V, 9 V & 4 amp DC supply
8) Volume of wooden casing = 0.10881 m³

VII. OBSERVATIONS

In the experimentation, observation for the temperatures and pressures at different point of window air conditioning system has been recorded at the interval of five minute. But in this paper, observations are shown for the quasi-steady state situation (after 15 minute) for the (1) without TEM (2) with single TEM and (3) with single TEM. Further, the observations are recorded by supplying 3V, 6V and 9V for the case (2) and (3) as mention above.

Nomenclature

T₁=Compressor inlet temperature (°c)
T₂=Condenser inlet temperature (°c)
T₃=Capillary inlet temperature (°c)
T₄=Evaporator inlet temperature (°c)
T₅=Temperature of space to be cooled (°c)

General Readings,
Inlet pressure of Compressor, P₁ = 3.7023 bar
Outlet pressure of Compressor, P₂ = 15.8370 bar

Table 1:

<table>
<thead>
<tr>
<th>Voltage supply (V)</th>
<th>Time (min)</th>
<th>T₁</th>
<th>T₂</th>
<th>T₃</th>
<th>T₄</th>
<th>T₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without TEM</td>
<td>15</td>
<td></td>
<td>-4</td>
<td>58</td>
<td>38</td>
<td>-8</td>
</tr>
<tr>
<td>With single TEM</td>
<td>3</td>
<td>15</td>
<td>-5</td>
<td>55</td>
<td>34</td>
<td>-7</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
<td>-5</td>
<td>59</td>
<td>35</td>
<td>-7</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td></td>
<td>-6</td>
<td>62</td>
<td>36</td>
<td>-7</td>
</tr>
<tr>
<td>With Double TEM</td>
<td>3</td>
<td>15</td>
<td>-3</td>
<td>64</td>
<td>40</td>
<td>-4</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
<td>-4</td>
<td>65</td>
<td>40</td>
<td>-6</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td></td>
<td>-4</td>
<td>69</td>
<td>41</td>
<td>-5</td>
</tr>
</tbody>
</table>

VIII. CALCULATIONS

Calculations were carried out for the all observations but in the present paper calculations are shown for one observation for each condition.

A. For without TEM

Enthalpies for the observation,

h₁ = 272.70 kJ/kg
h₃ = 97.73 kJ/kg

1) Refrigerating Effect:

R.E. = h₁ - h₃
   = 247.73 – 97.73
   = 150 kJ/kg

2) Work done:

W.D. = h₂ - h₁
   = 272.7 – 247.73
   = 24.97 kJ/kg

3) Co-efficient of Performance:

C.O.P. = R.E/W.D.
   = 150/24.97
   = 6.00

4) Mass of Refrigerant:

M.O.R = (TR*210)/R.E.
   = (1.5*210)/150
   = 2.1 kg/min

5) Power Consumption:

P.C. = M.O.R * (W.D.)/60
   = 2.1(24.97)/60
   = 0.87395 Kw
B. For with single TEM (Voltage = 3 V)

Enthalpies for the observation,

\[ h_1 = 254.086 \text{ kJ/kg} \]
\[ h_2 = 281.78 \text{ kJ/kg} \]
\[ h_3 = 82.688 \text{ kJ/kg} \]

1) Refrigerating Effect:

\[ \text{R.E.} = h_1 - h_3 \]
\[ = 254.086 - 82.688 \]
\[ = 171.398 \text{ kJ/kg} \]

2) Work done:

\[ \text{W.D.} = h_2 - h_1 \]
\[ = 281.78 - 254.086 \]
\[ = 27.694 \text{ kJ/kg} \]

3) Co-efficient of Performance:

\[ \text{C.O.P.} = \frac{\text{R.E.}}{\text{W.D.}} \]
\[ = 171.398/27.694 \]
\[ = 6.188 \]

4) Mass of Refrigerant:

\[ \text{M.O.R} = \frac{(TR \times 210)}{\text{R.E.}} \]
\[ = \frac{(1.5 \times 210)}{171.398} \]
\[ = 1.8378 \text{ kg/min} \]

5) Power Consumption:

\[ \text{P.C.} = \text{M.O.R} \times \frac{(\text{W.D.})}{60} \]
\[ = 1.8378 \times \frac{27.694}{60} \]
\[ = 0.8482 \text{ kW} \]

C. For with double TEM (Voltage = 3 V)

Enthalpies for the observation,

\[ h_1 = 248.86 \text{ kJ/kg} \]
\[ h_2 = 268.40 \text{ kJ/kg} \]
\[ h_3 = 100.00 \text{ kJ/kg} \]

1) Refrigerating Effect:

\[ \text{R.E.} = h_1 - h_3 \]
\[ = 248.86 - 100.00 \]
\[ = 148.86 \text{ kJ/kg} \]

2) Work done:

\[ \text{W.D.} = h_2 - h_1 \]
\[ = 268.40 - 248.86 \]
\[ = 19.54 \text{ kJ/kg} \]

3) Co-efficient of Performance:

\[ \text{C.O.P.} = \frac{\text{R.E.}}{\text{W.D.}} \]
\[ = 148.86/19.54 \]
\[ = 7.61 \]

4) Mass of Refrigerant:

\[ \text{M.O.R} = \frac{(TR \times 210)}{\text{R.E.}} \]
\[ = \frac{(1.5 \times 210)}{148.86} \]
\[ = 2.116 \text{ kg/min} \]

5) Power Consumption:

\[ \text{P.C.} = \text{M.O.R} \times \frac{(\text{W.D.})}{60} \]
\[ = 2.116 \times \frac{19.54}{60} \]
\[ = 0.684 \text{ kW} \]

IX. RESULTS

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameters</th>
<th>Without TEM</th>
<th>With Single TEM</th>
<th>With Double TEM</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>Refrigerating Effect (kJ/kg)</td>
<td>150</td>
<td>150.1</td>
<td>153.4</td>
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<tr>
<td>2</td>
<td>Work done (kJ/kg)</td>
<td>24.97</td>
<td>23.80</td>
<td>31.74</td>
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<tr>
<td>3</td>
<td>Mass of Refrigerant (kg/min)</td>
<td>5.902</td>
<td>4.83</td>
<td>5.16</td>
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</table>

Table 2:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameters</th>
<th>With Double TEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Refrigerating Effect (kJ/kg)</td>
<td>148.86</td>
</tr>
<tr>
<td>2</td>
<td>Work done (kJ/kg)</td>
<td>25.03</td>
</tr>
<tr>
<td>3</td>
<td>Mass of Refrigerant (kg/min)</td>
<td>2.1323</td>
</tr>
<tr>
<td>4</td>
<td>C.O.P. Of Cycle</td>
<td>5.902</td>
</tr>
<tr>
<td>5</td>
<td>Power Consumption (kW)</td>
<td>0.689</td>
</tr>
</tbody>
</table>

Table 3:

X. CONCLUSION

From results it has been found that,

- The performance of window air conditioning system can be improved by introducing TEM. Form the observations, it has been found that maximum C.O.P. of air conditioning system is obtained when 3 volts is supplied to single TEM. The C.O.P. is increased by 5.16%, work done and power consumption reduced by 4.7% and 5.14% respectively with single TEM when 3 V is supplied to TEM.
- From the observations, the performance of window air conditioning system is increased when two TEM is introduced. The maximum C.O.P. of system with double TEM is also obtained when 3 volt is supplied to double TEM. The C.O.P. is increased by 26.83%, work done and power consumption reduced by 21.75% and 21.16% respectively with double TEM when 3 V is supplied to TEM.

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