Development of High Efficiency Small Room Air Conditioner- Application of Dew Point Cooling System

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\textbf{Abstract. }The objective of this study is to design and simulate a vapour-compression refrigeration cycle and dew point cooling system. Besides, to identify air characteristic in Riyadh city which is has high temperature 44\textdegree C with relative humidity 25% the identification of climate is to create appropriate environment and high efficiency cooling. However, the cooling load for small room 20 m\textsuperscript{2} reached to 3.9 kw because the temperature is very hot. The simulation for refrigeration and dew point cooling system shows the air distribution inside the room, from simulation the air distribution remains constant from 0s to 1 hour because it supplies air each cycle. The velocity for air conditioning is 2 m/s to provide comfort zone. The refrigerant R410a is taken as work fluid for refrigeration cycle.

1. Introduction
In recent years, the temperature getting hotter in summer, this increasing in temperature effect on the building which leads to increase the requirement for air conditioning. While vapour-compression refrigerant cycle is the most widely used system for air-conditioning, Refrigeration cycle is a close system process, a working fluid of the cycle is returned to initial state at the end of the cycle and recirculated. Refrigeration cycle consist of compressor and condenser, expansion and evaporator, the refrigerants carried in compressor cycle is very harmful to the environment and it consumes a large amount of energy \cite{1}. These factors lead to developed of evaporative cooler. This evaporative cooling of the air consumes less energy compared with traditional cooling system and it is an environmental friendly system.

However, the state of the air is completely important for the efficiency of the evaporative air cooling system. Middle East region climate is hot and dry climate which is suitable conditions for evaporative air cooling system. This system gives sufficient cooling but the increasing of humidity gives the feeling of discomfort. However, evaporative cooling technology improved by Russian scientist Valery Maisotsenko which is Maisotsenko Cycle (M-Cycle), one of type of dew point cooling system. M-Cycle is a new cooling system with more efficiency and less energy consumption than the conventional cooling system, M-Cycle is friendly to environment and it does not use Freon gas or compressor. This cooling system use simple cross heat exchanger, the heat mass exchanger does not let humidity to be added into product air stream to give a comfortable feeling \cite{2}. The objective of dew point cooling system to overcome the limitation of the indirect evaporative cooling by extracting a one channel of product air to become a working air and cooling the product air to its dew point \cite{3}.
2. Methodology
The heat load of the small room determined by using Heat Balance Method [4] where outdoor parameter using Riyadh city. The operational conditions of the compressor and the capillary tube should be designated. Designing each component one by one, and calculating the pressure drops in the condenser and the evaporator, a deviation from the ideal cycle line will occur. Determine heat transfer occur in heat mass exchanger. Therefore, a pre-determined state should be chosen and the design should be started from this state.

3. Results and Discussions

3.1. Cooling load results
External load result for small room area 20 m²

| Heat Source | Q (W) |
|-------------|-------|
| Wall        | 997.605 |
| Roof        | 793.651 |
| Floor       | 672.54 |
| window      | 217.75 |
| Door        | 38.91 |
| **Total**   | **2720.375** |

While, internal load result for small room area 20 m²

| Heat Source | Q (W) |
|-------------|-------|
| People      | 343   |
| Lights      | 516   |
| Equipment   | 360   |
| **Total**   | **1221** |

The total cooling load is sum of heat gained by external and internal load, therefore the heat gained should be removed from the space to maintain the temperature to provide acceptable range.

\[ Q_{total} = Q_{external} + Q_{internal} \]
\[ Q_{total} = 1221 + 2720 \]
\[ Q_{total} = 3941.357 \, W \]

3.2. Simulation results by ANSYS CFX

3.2.1. Dew point cooling system air distribution & velocity
Figure 1. Air distribution and velocity for dew point cooling system

Figure 1 shows the dew point cooling system air velocity is 2 m/s and the air distribution inside the room and at the end the air will pass through the outlet.

3.2.2. Vapour-compression refrigeration cycle air distribution & velocity

Figure 2. Air distribution and velocity for vapour-compression refrigeration cycle

3.2.3. Thermal distribution inside the room
Figure 3 shows that the red colour in the figure is the heat transfer inside the room wall from outside temperature around 42°C and inside temperature is 24°C which is blue colour.

3.3. Discussions
The cooling load has been done regarding to Riyadh climate for small room with 20 m², total cooling load is 3.9 KW. The outdoor design temperature is 44°C where with this high temperature led to increase the total cooling load. The comfort zone temperature provided for small room is 24°C while the relative humidity is 45%.

The working fluid to design the vapour-compression refrigeration cycle is R410a where the evaporator efficiency is 15% to ensure that the performance of evaporator remain constant and avoid the dust that may affect the evaporator. In addition, 6-15°C is the best temperature to discharge air to space and 10°C is the temperature of the evaporator. Temperature of compressor is 50°C with 1Mpa as low pressure and 3 Mpa as high pressure. The compressor has 21.83 ml/rev displacement volume with efficiency 85%.

The result shows the air distribution for dew point cooling system and refrigeration cycle where the air distribution for dew point cooling system remain constant after period time because for each cycle it provides new working fluid. While the result for refrigeration cycle, the air distribution change after period time because it circulates the working fluid. The result show that the heat transfer through the wall into the room with outside temperature 44°C.

4. Conclusion and recommendation
Through the calculation clarify that the maximum heat gained through, roof, window and wall by conduction heat transfer and this high heat gained due to the high temperature in the region. From detailed calculation it becomes clear the highest heat gained is through the wall. The room wall must contain more layer of material in order to prevent the heat enter through it. However, the total amount of heat gain to the room is 3.5 KW based on the maximum heat. The air-conditioning system type that will suitable to our case study is split air conditioner.

The efficiency of evaporator of refrigeration cycle can effect on cooling performance if the value of efficiency ignored, the size of evaporator related to the air velocity. High velocity gets less comfort with smaller size of evaporator. The air distribution clarify that the velocity has direct effect on the comfort zone.

The heat mass exchanger of dew point cooling system is only appropriate in dry climate because the system remains the moisture in the air constant. The feature of dew point cooling system is the dew point temperature of outdoor air is same with indoor air, also the specific humidity ratio same.
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