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Performance Enhancement of COP of Air Conditioning System using Hybrid Condenser

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Abstract

Currently energy conservation is one of the most important fields of research. This is mainly due to our dependence on energy supplies that are exhaustible and are getting depleted at a rapid pace. Rapid paced concretization and increasing pollution has led to a rise in national average temperature. This has led to increased usage of comfort cooling devices like the air conditioning systems, which in turn increase the load on the energy sector. The aim of this project is to show that by using an additional water cooled condenser, the COP of air conditioning system increases thereby decreasing system power consumption.

Keywords:*air conditioning, COP, Condensers, Reverse Carnot Cycle*

1. Introduction

Recent studies indicate that global temperatures are set to rise by as much as 8°C by 2100[1]. Much of this increase in temperature has been contributed to the rapid paced concretization and deforestation occurring throughout the developing world.This rise in temperature has led to exponentially growing energy consumption which in turn has increased pollution levels. Methods and technologies which increase or improve energy utilization efficiency are been given greater importance by the international community.

India, geographically lies near the equator and therefore experiences a tropical weather, which is usually hot and humid. Rising global temperatures and large amount of pollution have had a noticeable effect on the national average temperature, especially in the summer season.

As India's middle class grows, the demand for affordable living accommodations has also seen a sharp rise. This has led to concretization of major population centers with little room for green cover, leading to increased local average temperature. For the common man in India, air conditioning systems are no longer a luxury but a growing necessity.This has led to a growth in the usage of comfort cooling devices like the air conditioning systems. Sales of air conditioning systems in India during summer season have seen growth by 16%-18%, which in turn have increased power consumption, exerting enormous pressure on the energy sector leading to load shedding across major cities and villages. Any changes or improvement in the operating efficiencies of these system will have a direct noticeable impact on energy consumption and help reduce the burden on the energy sector.

Air conditioning systems are usually used for small to medium scaled residential and commercial buildings. Majority of the air conditioning systems in use are either window mounted air conditioning or split air conditioning systems. These account for a large share in domestic power consumption. The performance of air conditioning systems depends on the heat transfer between coils and the airflow between them. Majority of this type of air conditioning systems are air cooled.

The power consumption of an air conditioner depends primarily on two factors. The output of a given rate of cooling and the entering temperature of medium for condenser cooling. To obtain high Co-efficient of Performance (COP) we can either decrease the temperature of the condenser or increase the temperature of the evaporator. Any decrease in the temperature of the condenser will result in the increase in performance of the conditioning system, thereby reducing the power usage and improving overall efficiency.

2. Literature Review

The following literature review describes important research results regarding the cooling of condenser of an air cooling system

- **Goswamiet. Al. (1993)** –Employed an evaporative cooling on existing 2.5 ton window air conditioning system by inject water from top by a small water pump on four media pad around the condenser. They reported the electric energy saving of 20% for the retrofitted system when ambient air temperature was 340C. They used a simple and cheapest way for cooling ambient air temperature

is employing the evaporative cooling system which results in decrease in ambient air temperature before it passes over the condenser coil[5].

- **W.Leidenfrost and B.Korenic(1979)-**In this wetted the condenser of refrigeration or heat pump system makes it possible to exchange the condenser load at lower temperature. Wetted heat exchangers require less extended surfaces and can operate effectively with bare tubes only [6].

- **Vrachopouloset. Al.(2005)** - developed an incorporated evaporative condenser, which was installed with a cooling water sprinkle network in the front. In this method water was directly sprayed into air stream. Since the air filled with water droplets was directly induced to the condensing unit corrosion problem possibly occurred on equipment [3].

- **Chow et. Al. (2002)**-reported that if the on-coil temperature of a condensing unit were raised by 10C, the coefficient of performance (COP) of the air conditioner would drop by around 3%. In addition, if this temperature remained above 318K for an extended period, the air conditioner would trip because of the excessive condenser working pressure[1].

3. Experimental Setup

A window air conditioner of 0.75 ton refrigeration capacity was selected. The unit has a single electricity phase reciprocating compressor. The condenser and evaporator coils are made of copper with smooth inner and outer surfaces. The modified setup is shown in fig 1.

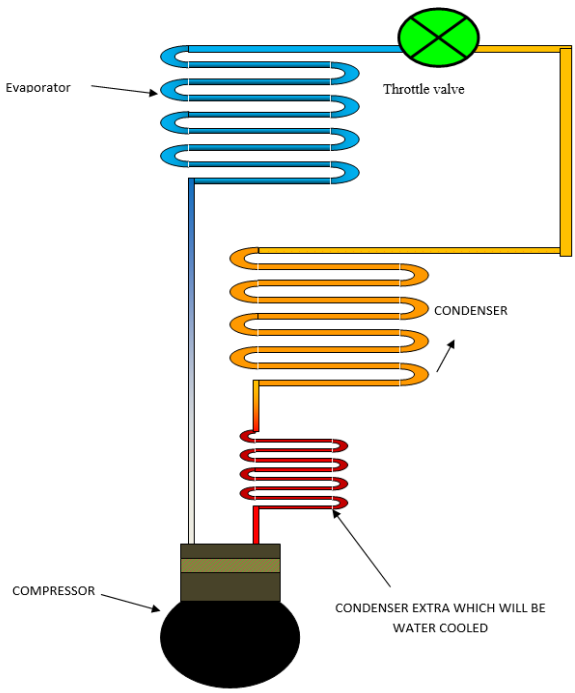

Fig.1 Experimental setup

Fig.2 Experimental setup

An additional water cooled condenser was added in between the air cooled condenser and the compressor. The output of the air cooled condenser led to the input of the water cooled condenser and the output of the water cooled condenser led to the input of the compressor. Temperature and pressure gauges were also installed at the inlet and outlet of the evaporator, and both the condensers. R134a was the refrigerant used in the experimental setup.

4. Experimental Analysis

Table 1 Experimental procedure parameters Stage 1

Sr. No	T	T_1	T_2	T_3	T_4	P_1	P_2
1	00	41.3	36.7	23	28.9	250	78
2	15	44.1	39.9	21.4	29.3	265	75
3	30	45.9	42.3	20.6	27.9	270	78
4	45	47.7	45.9	19.7	27.4	280	78
5	60	49.1	49.4	19	26.9	280	80

Table 2 Experimental procedure parameters Stage 2

Sr. No	T	T_1	T_2	T_5	T_3	T_4	P_1	P_2
1	00	39.5	35.1	29.4	21.5	29.4	250	78
2	15	41.3	36.8	30.9	20.5	29.3	265	75
3	30	42.1	36.8	30.9	19.9	29.2	265	78
4	45	43.5	37.1	32.1	19	28.7	270	78
5	60	44.3	37.9	32.5	18.1	27.9	280	80

T - Time in (minutes)
T_1 - Temperature of condenser at inlet (°C)
T_2- Temperature of condenser at outlet (°C)
T_3 - Temperature of evaporator at inlet (°C)
T_4 - Temperature of evaporator at outlet (°C)

T_5 - Temperature of water cooled condenser at outlet
P_1 – Pressure in condenser (Psi)
P_2 – Pressure in compressor (Psi)

Preliminary experiment was done to prepare the set up for obtaining reliable data. To set up a baseline for comparison and also to observe the effect of the addition of water cooled compressor on the air conditioner, each experiment was performed in two successive stages.

In the first stage, the normal air conditioner was used for experimentation without using the water cooled condenser and the data was recorded after achieving steady state conditions.

In the second stage, the water cooled condenser was added and the data was recorded after achieving steady state conditions. The weather or ambient conditions for both the experiments was the same.

Many tests were performed to determine the effect of addition of water cooled condenser on the COP of the air conditioning system. The results of experimental run of stage 1 are shown in table 1 and the results of experimental run of stage 2 are shown in table 2

5. Results and Calculations

By the Addition of water cooled condenser there is a noticeable change in the condenser outlet temperatures.Co-efficient of performance of the air conditioned system is the ratio of heat extracted by an evaporator to the net work done.

$$COP = Qr \div Wn$$
$$COP = (T4 - T3) \div (T1 - T4)$$

Q_a– Refrigeration effect
W_n – Net work done

Table 3COP Calculation for stage 1

Reading No.	COP
1	0.475
2	0.436
3	0.405
4	0.381
5	0.361
Average	0.411

Net Work Done (Wn) for Stage 1 = Qr÷ Average COP
Wn = (0.75 x 3.5) ÷ 0.4116
Wn = 6.377KW

Table 4COP Calculation for stage 2

Reading No.	COP
1	0.782
2	0.733
3	0.720
4	0.653
5	0.601
Average	0.701

Net Work Done (Wn) for Stage 2
Wn = (0.75 x 3.5) ÷ 0.701
Wn = 3.7446KW

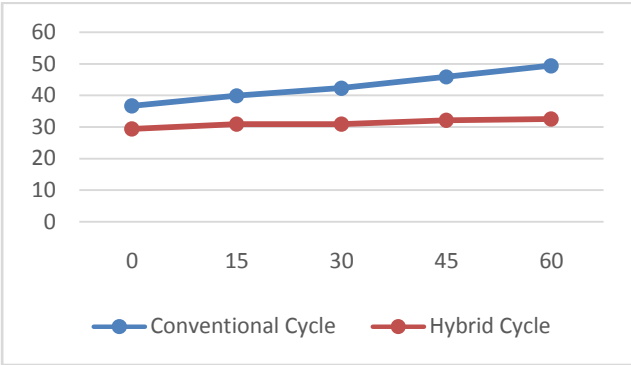

Fig.3 Condenser Outlet Temperature

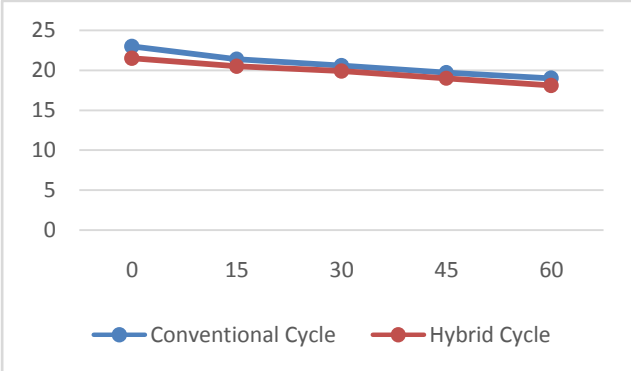

Fig.4 Evaporator inlet Temperature

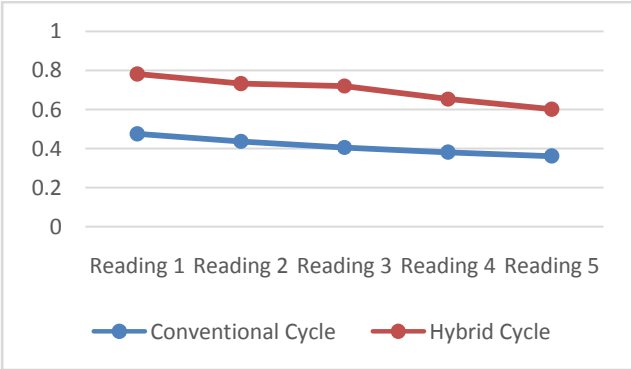

Fig.5COP Comparison

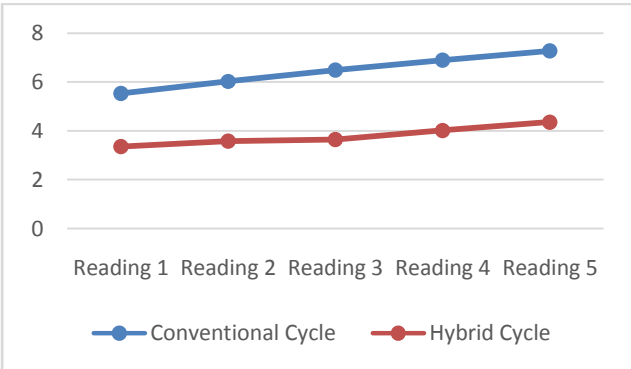

Fig.6 Net Work Comparison (KW)

6. Conclusions

1) The average COP of the hybrid air conditioning systems was 0.701 while the average COP of conventional air conditioning systems was 0.411. The average COP of the hybrid air conditioning systems was found to be higher than the average COP of the conventional air conditioning system. The cooling capacity and Coefficient of performance of the air conditioning system increased considerably.

2) The average net work done or power consumed by the conventional air conditioning systems was 6.377KW while the average net work done for the hybrid AC system was 3.744KW. Experimental results revealed that with the hybrid air conditioning systems the power consumption decreased considerable.

3) The hybrid air conditioning system was found to be 7% more efficient than its conventional counterpart.

4) The design change for employing hybrid air conditioning systems in a window air conditioner based on the local price index shows that the energy saved can pay for the cost associated with retrofitting the condenser in less than a year.

7. References

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