THERMAL PERFORMANCE ANALYSIS OF WINDOW AC WITH EVAPORATIVE COOLING OF CONDENSER

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Abstract: Many air conditioners are introduced in the market for the purpose of human comfort like window ac, split ac and central ac. Window ac is commonly used for inhouse comfort. In this work main concentration is on investigation of performance of window ac by using evaporative condenser. A novel evaporative condenser is developed and performance testing of window ac is carried out in moderate climate conditions. The effect of ambient air temperature on the performance of window ac was studied. The experimental results with air cooled condenser showed that, an increase in the ambient air temperature has a negative effect on COP. Performance testing of window ac with evaporative condenser shows 10.71% savings in energy, up to 5.51% enhancement in coefficient of performance and 2.58% increase in refrigeration effect over air cooled condenser.

***Index Terms* – Window ac, air cooled condenser, Evaporative condenser.**

I. INTRODUCTION

Hot and dry days of year makes human uncomfortable and reduces their working efficiency. Hence application of conventional vapour compression air conditioners in such condition is essential. Increase in outside temperature results in poor heat rejection over condenser which increases the power consumption of compressor [1]. According to international institute of refrigeration nearly 15% of worldwide electricity consumption is only for refrigeration purposes. Commercially, there are two types of condensers used, one is air-cooled and second is water-cooled. Use of water as condensation media is associated with more complex maintenance and biological hazards hence small and medium power air conditioning systems use air as a means of condensing. One of the ways to improve the performance of air conditioning system that uses air-cooled condenser is to decrease the ambient air temperature before entering condenser coil. As far as air temperature is moderate it seems reasonable, but when air temperature approaches to 45°C and above the performance of condenser reduces. This causes increase in compressor work and hence reduces COP of system. Evaporative cooling is low cost and environment-friendly option to cool the condenser of refrigeration system. Ebrahim Hajidavalloo [1] introduced a new window air conditioner with evaporative cooling in the condenser. The experimental results show power consumption decreases by about 16% and the coefficient of performance increases by 55%. Aditya P. Sawant et al.[2] conducted experiments for three different cycles; the conventional cycle, evaporative cooling cycle without the condensate reuse and evaporative cooling cycle with the condensate reuse. Also two different pads khus and cellulose-bounded were tested. Evaporative cooling-assisted cycle that reused the condensate was proven better. Honeycomb-structured cellulose-bounded media pads have edge batter over the khus grass type media pads. M. Ashok Chakravarthy et al. [3] analyzed the window air conditioning system for alternative refrigerant of R-22. They concluded that the performance of a specific alternative varies from one application to another. Vivek W. Khond [4] investigated a performance of Desert Cooler using different pad materials. Water consumption was observed maximum for wood wool pad and minimum for coconut coir at same fan speed. Rupeshkumar V. Ramani et.al [5] studied effects of ambient conditions on performance of air cooled condenser. Results show air cooled condensers becomes less effective under high ambient temperature. Above researches address the different aspects of direct evaporative cooling of air used for air cooled condenser. The present work focuses on evaporative cooling of the condenser coils by cooling pad material.

II. EXPERIMENTAL SET UP

Test rig description and specifications

A window air conditioner having 1 Ton of refrigeration capacity is taken for test. The unit is having a single-phase rotary compressor. The coils of condenser and evaporator are made up of copper with a smooth inner tube surface. Interrupted type of fin used in condenser and evaporator which is a very widely accepted method of increasing the heat transfer coefficient and creating more turbulent mixing on the air side of the heat exchanger. Condenser fins and evaporator fins both are made up of aluminium. The overall dimensions of the window air conditioner are 615× 555× 375 (length× width× height) mm. Fan motor is single phase, 230V 50Hz, 900 RPM and 70W. The system is having R134a as refrigerant. The constant heat load of 1.25 kW is applied to the system.

Instrumentation

Two pressure gauges (0-14 bar) and (0-28 bar) are fixed at compressor inlet and outlet respectively to measure the condenser pressure (Pc) and evaporator pressures (Pe). Six thermocouples are used in different places. Four thermocouples measure the temperature at condenser inlet (T_{ci}), condenser outlet (T_{co}), evaporator inlet (T_{ei}) and evaporator outlet (T_{eo}) respectively.

Figure 1 Experimental setup for window ac

Other two thermocouple measures ambient temperature (T_a) and room air inlet temperature. Voltmeter (V) and ammeter (I) are used to measure compressor power. One Hygrometer is provided to measure wet bulb and dry bulb temperatures of inlet and outlet air to evaporator. Energy meter is used to measure actual power consumption of compressor. Volume flow rate of refrigerant (LPH) is measured by using rotameter.

Experimental procedure

The test procedure adopted for recording temperatures, flow rate and pressure drop data is as follows.

- Turn on the main switch to start the system and keep the system running for 10 minutes to reach the steady state condition.
- After the steady state note down the refrigerant side pressures, temperatures and flow rate.
- Note down the voltmeter and ammeter readings.
- Repeat the procedure for next reading.

Table 1 observation table with air cooled condenser

Temperature of refrigerant (°C)				Ambient temperature (°C)	Pressure (bar)		Voltage	Current	Volume flow rate(LPH)
T_{ci}	T_{co}	T_{ei}	T_{eo}	T_a	Pc	Pe	V	I	
69	30	8	18	24	2.15	8.24	224	1.4	25
71	33	9	19	25	2.15	8.24	239	1.3	26
71	34	6	20	26	2.35	8.82	225	1.4	26
72	36	9	20	27	2.35	9.81	231	1.4	27
73	36	8	20	28	2.35	9.81	234	1.4	27
75	40	9	22	29	2.45	10.6	233	1.4	28
76	40	8	22	30	2.45	10.8	225	1.5	28

Table 2 results table for air cooled condenser

Enthalpy of refrigerant (kJ/kg)				Mass flow rate of refrigerant (kg/s)	Refrigeration effect (kW)	Heat rejected (kW)	Compressor work (kW)	COP
h_{ci}	h_{co}	h_{ei}	h_{eo}	m_r				
452.13	241.72	241.72	414.09	0.0082	1.413	1.725	0.311	4.53
454.18	246.07	246.07	415.88	0.0084	1.426	1.748	0.321	4.43
453.3	247.53	247.53	415.44	0.0084	1.410	1.728	0.318	4.43
452.81	250.46	250.46	415.44	0.0087	1.435	1.760	0.325	4.41
453.87	250.46	250.46	415.44	0.0087	1.435	1.769	0.334	4.29
454.78	256.38	256.38	417.03	0.0089	1.429	1.765	0.335	4.25
455.54	256.38	256.38	417.03	0.0089	1.429	1.772	0.342	4.17

III. EXPERIMENTAL SET UP WITH EVAPORATIVELY COOLED CONDENSER

Fabrication and assembly of media pad and water circulation arrangement

Figure 2 Evaporative condenser

Air cooled condenser coil is covered with wood wool cooling pad material after removing fins. Wood wool is placed over the condenser in such a way that condenser coils are completely surrounded by cooling media. Water sump of mild steel material is made to supply water over the pad material. The dimensions of water sump are 450× 450×300 mm (L× B × H). Suitable cooler pump is selected on the basis of head requirement. This pump along with perforated pipes serves the purpose of re-circulating and spraying the water on cooling media. The system is charged with R-134a refrigerant. Air will get sucked by condenser fan and blow over condenser coil where cooling media facilitate evaporation of water.

Table 3 observation table for evaporative condenser

Temperature of refrigerant (°C)				Ambient temperature (°C)	Pressure(bar)		Voltage	Current	Volume flow rate (LPH)
T_{ci}	T_{co}	T_{ei}	T_{eo}	T_a	Pc	Pe	V	I	
69	30	6	18	24	8.24	2.15	220	1.4	25
70	31	8	19	25	8.24	2.15	226	1.4	26
73	32	8	20	26	9.81	2.15	225	1.4	26
74	33	9	21	27	9.81	2.25	229	1.4	26
75	33	11	22	28	9.81	2.25	220	1.5	26
77	36	11	24	29	10.3	2.35	231	1.4	27
77	36	10	24	30	10.3	2.35	233	1.4	27

Table 4 results table for evaporative condenser

Enthalpy of refrigerant (kJ/kg)				Mass flow rate of refrigerant (kg/s)	Refrigeration effect (kW)	Heat rejected (kW)	Compressor work (kW)	COP
h_{ci}	h_{co}	h_{ei}	h_{eo}	m_r				
452.13	241.72	241.72	414.09	0.0082	1.413	1.725	0.311	4.53
453.2	243.2	243.2	415	0.0083	1.425	1.743	0.317	4.49
454	244.61	244.61	415.8	0.0083	1.420	1.737	0.317	4.48
454.92	246.06	246.06	416.56	0.0085	1.449	1.775	0.326	4.44
456.5	246.06	246.06	417.8	0.0085	1.459	1.788	0.328	4.43
457.35	250.46	250.46	419.05	0.0087	1.466	1.799	0.333	4.40
457.35	250.46	250.46	419.05	0.0087	1.466	1.799	0.333	4.40

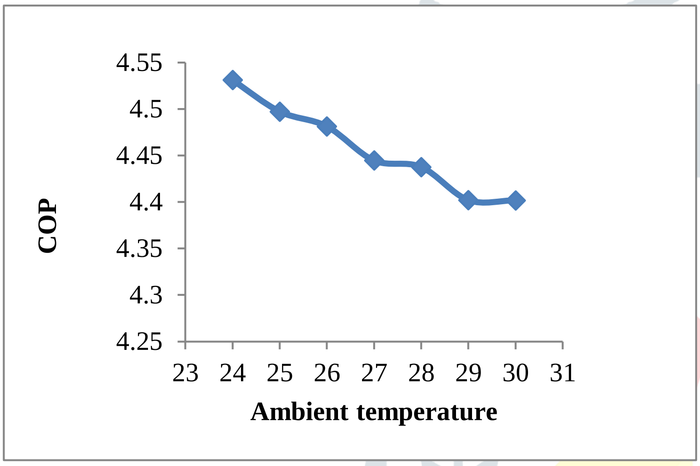
IV. RESULTS AND DISCUSSION

The test was conducted in moderate climatic conditions for two cycles; air cooled and evaporatively cooled condenser. Window ac is kept on for one hour and initial and final readings of energy meter are recoded to calculate energy consumption. The results obtained from experimental observation at ambient temperature of 30 °C and constant heat load of 1.25 kW on window ac are tabulated as below. It is observed that evaporative condenser shows more improved results in terms of energy consumption, refrigeration effect and COP over conventional condenser.

Table 5 performance comparision between conventional and evaporative condenser

	Conventional condenser	Evaporative condenser
Total energy consumed (kW)	0.62	0.56
Saving in energy (%)	-	10.71
Refrigeration effect (kW)	1.429	1.466
Increase in refrigeration effect (%)	-	2.58
COP	4.17	4.40
Enhancement in COP (%)	-	5.51
Degree of sub cooling (°C)	5	8
Refrigeration flow rate (kg/s)	0.0089	0.0087

Figure 3 shows the variation of system performance (COP) with respect to ambient temperature. It can be clearly seen that as ambient temperature rises, system performance goes on decreasing. Within the ambient temperature of 24°C- 30°C coefficient of performance is reduced by 3%. The system performance (COP) of window ac with the use of air cooled condenser and evaporative condenser is shown in figure 3. It can be clearly seen that amongst the two cycles evaporatively cooled condenser cycle shows improvement in COP. This is due to increase in refrigeration effect and reduction in power consumption by virtue of evaporative cooling of condenser. Figure 4 shows benefits from evaporative condenser in terms of refrigeration effect and power consumption. It is observed that with the use of evaporative condenser refrigeration effect is improved by 2.58 %. Energy savings of 10.71 % is achieved by using evaporative condenser over air cooled condenser.



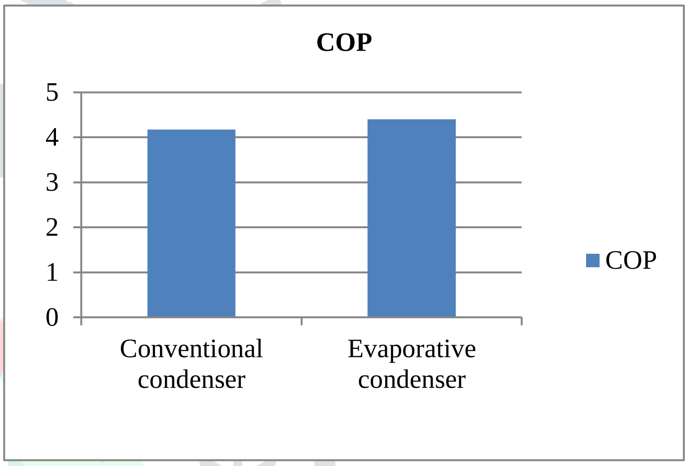


Figure 3 Variation of cop with ambient temperature (left) and cop for conventional and evaporative condenser (right)

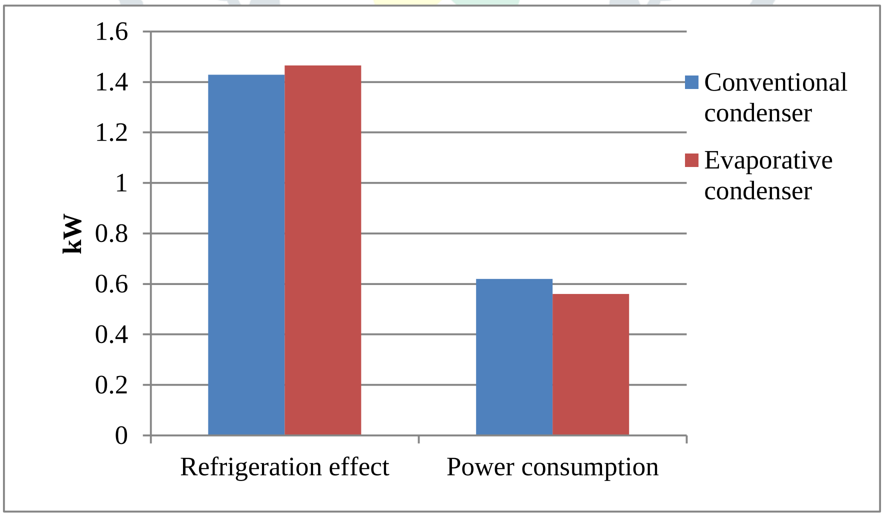


Figure 4 Refrigeration effect and power consumption of conventional and evaporative condenser

V. CONCLUSIONS

Window ac is modified with evaporatively cooled condenser.

- Evaporatively cooled condenser results in 10.71% saving in energy, 2.58% increase in refrigeration effect and 5.51% enhancement in COP over air cooled condenser.
- Degree of sub cooling and refrigeration effect is increased by using evaporative cooled condenser instead of air cooled condenser.
- As the temperature increases, the mass flow rate of the refrigerant increases in both cases

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