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Research Article

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Performance study on split air-conditioning system in hot climate regions

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Abstract Management of the thermal performance of the split air-conditioning system and reducing the negative effect of the global environment can be achieved by evaluating the coefficient of performance. The heat dissipation from the condenser of split air- conditioning system mainly control the performance of the split air- conditioning system. In the current investigation, experiments were carried out to study the effect of the ambient air temperature on the air temperature difference across the condenser (ΔT_{cond}), condenser temperature (T_c), the total electrical power consumption (P) consequently the coefficient of performance (C.O.P) of the split air- conditioning system. The results show that increasing the ambient air temperature decreases the temperature difference across the condenser while it increases the condenser temperature and power consumption. The C.O.P of the split air-conditioning system decreases with increasing the ambient air temperature.

Keywords Split air-conditioning system; ambient air temperature; condenser temperature; C.O.P, hot climate.

Introduction

Recently, the usage of split-air conditioning system in hot countries is a big challenge in the area of heating ventilation and air conditioning. The coefficient of performance (C.O.P) of these units depends on the temperature of ambient air as well as on the space between the condenser and the adjacent wall [1]. Sometimes, large number of condensing units release high rate of heat rejected, hence degraded its thermal performance. In hot weather countries where the ambient temperature in summer seasons is more than 50 ^{0}C the coefficient of performance of the cycle is reduced considerably [2]. Moreover, increasing the condenser temperature has a negative effect on the power consumption of split-air conditioning systems. Increasing each degree in condenser temperature decreases the C.O.P of split-air conditioning systems by 2-4% [1]. The condenser mainly is cooled either by sensible, latent or both. Air-cooled condensers is more convenient for small-scale systems due to its advantages of easy maintenance with compact size [3]. The driving force of eliminating the heat dissipated from the condenser is the temperature difference between the surface temperature of condenser and the ambient temperature. Therefore, increasing the ambient air temperature reduces the heat transfer rate causes reducing the C.O.P of the split air conditioning systems [4-5].

Using TRNSYS program, the performance of improved air-cooled chillers using variable speed fans of an air-cooled screw-chiller under various operating conditions was developed by Ya and Chan [5]. The results indicated that the optimum set-point temperature of the condensing unit is a function of cooling capacity and the wet-bulb temperature of ambient outdoor air. Hajidavalloo [6] investigated the thermal performance of the window-air-conditioning system for dry and hot climate regions associated a high temperature area. The experimental results showed that thermodynamic characteristics of the window-air-conditioner decreases with increasing the power consumption for increasing the outdoor temperature from 45 ^{0}C to 46 ^{0}C. An experimental investigation on the thermal performance of split air conditioning system for different atmospheric temperatures ranged from 20 ^{0}C to 45 ^{0}C was carried out by Bilgili et. al. [7]. The results showed that increasing the atmospheric temperatures from 20 ^{0}C to 45 ^{0}C increasing the power consumption by 47%. As well as, rising the atmospheric temperature from 20 °C to 46 °C deteriorates the coefficient of performance of the split-air conditioning system by about 38%. Kumlutas et al. [8] presented a three-dimensional model to simulate the indoor units and heat transfer and fluid flow of the split air-conditioner. Joudi and Al-Amir [9] studied experimentally the performance of air conditioning systems utilizing alternative refrigerants such as R-22, R-290, R-407C and R-410A on the optimum refrigerant charge, C.O.P, cooling capacity, power consumption, pressure ratio, power per ton of refrigeration. The results showed that the C.O.P decreased for all refrigerants, as the ambient temperature increased and the C.O.P for 1 and 2 TR systems using R410A were found to be the lowest among the all tested refrigerants. Dawoud et al. [10] performed an analyses of a vapour compression refrigeration system with utilizing isobutene (R600a) as a refrigerant. The results indicated that increasing the condenser temperature decreased the C.O.P of the system.

In the previous studies, conventional air-cooled air-conditioning system has revealed its high condenser and compressor temperatures compared with those subjected to low ambient air temperature. The current investigation will present a comprehensive study on the split air-conditioning system for hot climate regions. The current experimental study will evaluate the temperature difference of air across the condenser (ΔT_{cond}), condenser temperature (T_c), the power consumption (P) consequently the coefficient of performance (C.O.P) of the system with varying the ambient air temperature changed from 33 ^{0}C to 59 ^{0}C.

Experimental set-up

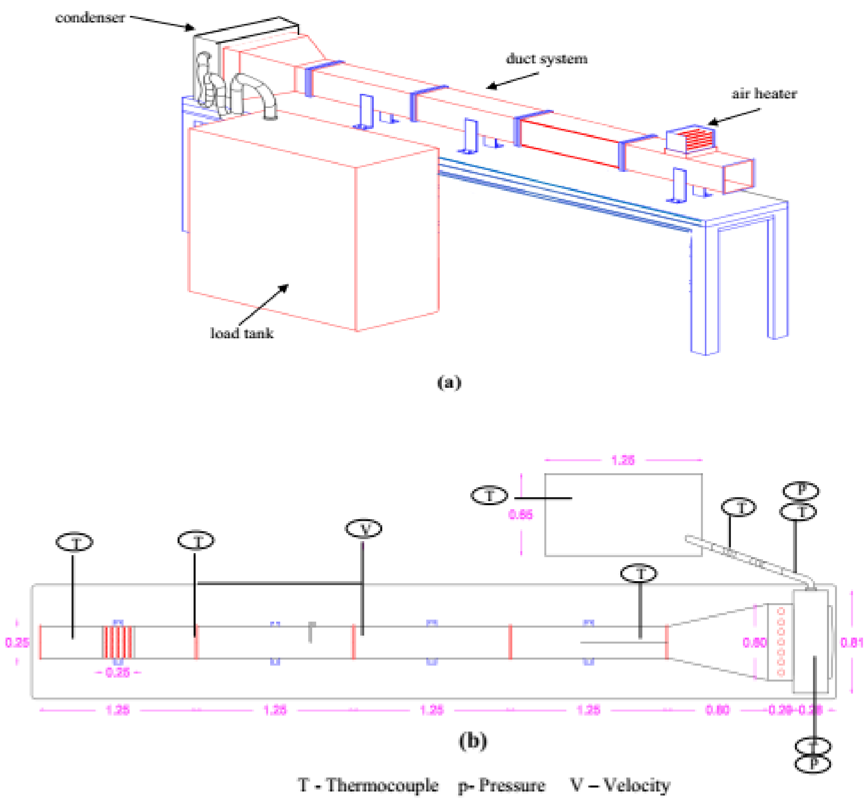

Figure 1: The experimental set-up
(a) 3-D view (b) top view with measuring locations

Figure 1 shows the general schematic of the split-air conditioning system with 10 kW air heater attached to the inlet of the system to regulate the ambient inlet temperature. All ducts were constructed from 0.08 cm thick galvanized steel sheets. The aspect ratio of the supply duct is 1:1 (25×25 cm^2). Length of duct is 500 cm divided to four pieces each piece of 125cm length. The last piece has an opening (10×10 cm^2) before the end 25cm. Duct (25×25 cm^2) is converting to (52×60 cm^2) with length 80 cm.

Data reduction

The following equations are used to calculate the desired parameter to study the performance of the split air-conditioning system. The total power consumption can be obtained using Eqn. (1) which considers power consumption of each component separately. Cooling capacity and C.O.P can be obtained using Eqn. (2) and Eqn. (3), respectively. In all equations, subscripts (1), (2), (3) and (4) stand for exit conditions from evaporator, compressor, condenser and capillary tube respectively as shown in Fig. (2).

$$P_t = P_{ele,comp.} + P_{fan,\,evap} + P_{fan,\,cond} \qquad (1)$$

where $P_{ele,\,comp.}$ is the electrical power input to the compressor, $P_{fan,\,evap}$ is the electrical power consumption by the evaporator fan and $P_{fan,\,cond}$ is the electrical power consumption by the condenser fan.

The cooling capacity of the system can be found from:

$$\dot{Q}_{evap} = \dot{m}_R(h_1 - h_4) \qquad (2)$$

The coefficient of performance (C.O.P) of split air-conditioning system can be defined in terms of total power consumption as follows [11]:

$$C.O.P = \frac{\dot{Q}_{evap}}{P_t} \qquad (3)$$

where $\dot{Q}_{evap}$ is the absorbed heat transfer rate in the evaporator, The compressor capacity can be obtained from:

$$P_{comp.} = \dot{m}_R\left(h_2 - h_1\right) \qquad (4)$$

where $P_{comp.}$ is the compressor power consumption and $\dot{m}_R$ is the mass flow rate of the refrigerant and h denotes the enthalpy. Here h_2 is the actual enthalpy at compressor exit and is defined as:

$$h_2 = h_1 + \frac{h_{2s} - h_1}{\eta_{ise}} \qquad (5)$$

where η_{ise} and η_{mech} are the isentropic efficiency and the mechanical efficiency of the compressor, respectively. The electric motor power can be found from the following equation:

$$P_{ele,comp.} = \frac{P_{comp.}}{\eta_{mech}\,\eta_{ise}} \qquad (6)$$

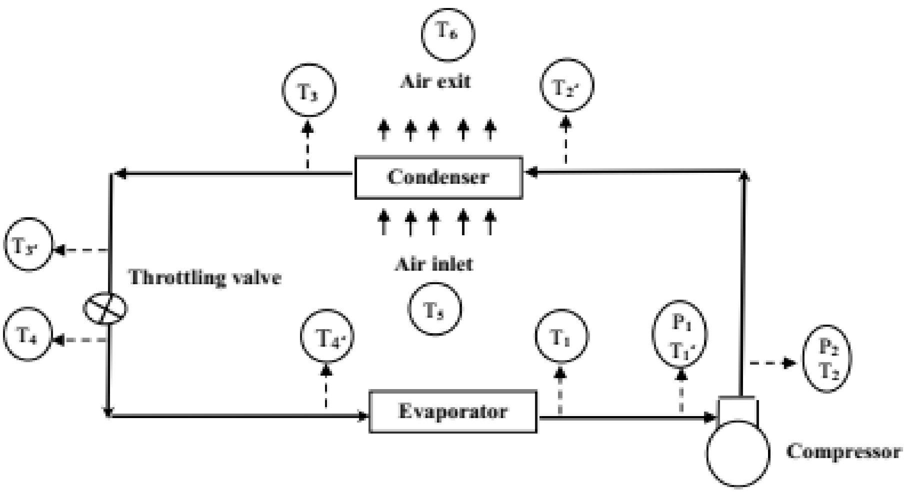

Figure 2: Location of pressure and temperature measurements

Experimental results and discussions

The experiments were carried out to study the effect of the increasing ambient air temperature on the temperature difference of air across the condenser (ΔT_{cond}), condenser temperature (T_c), the power consumption (P) consequently the coefficient of performance (C.O.P) of the system.

Air temperature difference across the condenser (ΔT_{cond}) relation to the outdoor ambient air temperature is shown in Fig. 3. It can be observed that the temperature difference across the condenser (ΔT_{cond}) decreases when the ambient air temperature increases. Moreover, it is observed that increasing the ambient air temperature from 33 ^{0}C to 50 ^{0}C decreases the air temperature difference across the condenser (ΔT_{cond}) significantly by 77 % while more increasing rather than 50 ^{0}C decrees he air temperature difference across the condenser (ΔT_{cond}) slightly by 10 %.

The effect of the ambient air temperature on the condenser temperature (T_c) is shown in Fig. 4. It is observed that, increasing the ambient air temperature increases steady the condenser temperature. Furthermore, increasing the ambient air temperature from 33 to 59 ^{0}C, increases the condenser temperature (T_c) by nearly 34%.

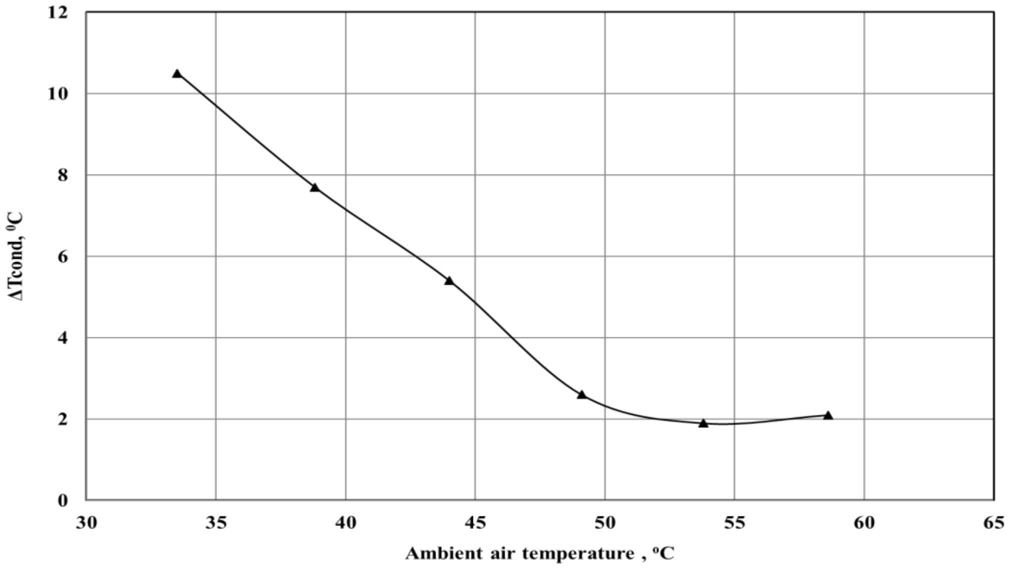

Figure 3: Impact of ambient air temperature on the air temperature difference across the condenser (ΔT_{cond})

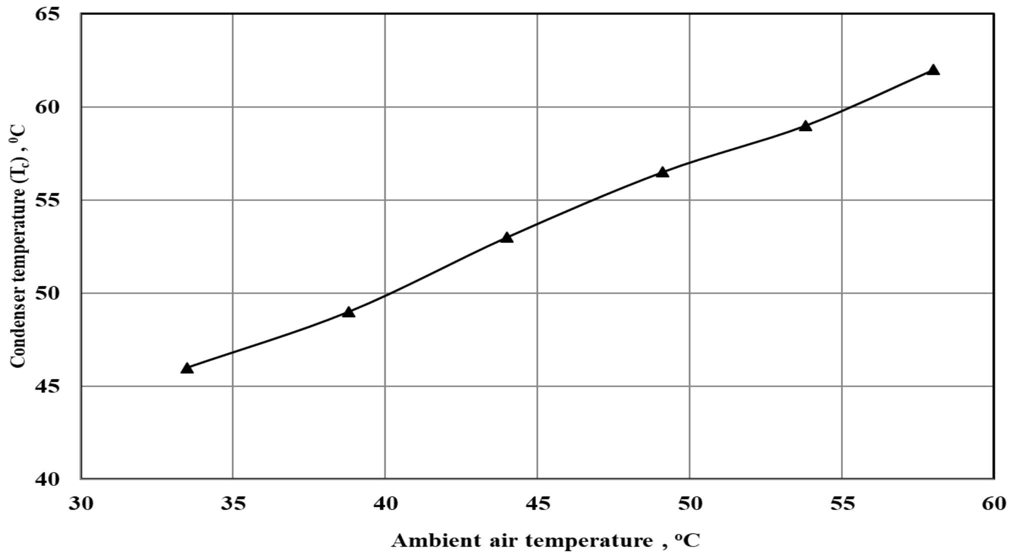

Figure 4: Impact of the ambient air temperature on the condenser temperature (T_c)

Effect of the ambient air temperature on the total power consumption (P) is illustrated in Fig. 5. The results indicated that the power consumption increases when the ambient air temperature increases. Furthermore, increasing the ambient air temperature from nearly 33 to 59 ^{0}C leads to increasing the power consumption by 33 %.

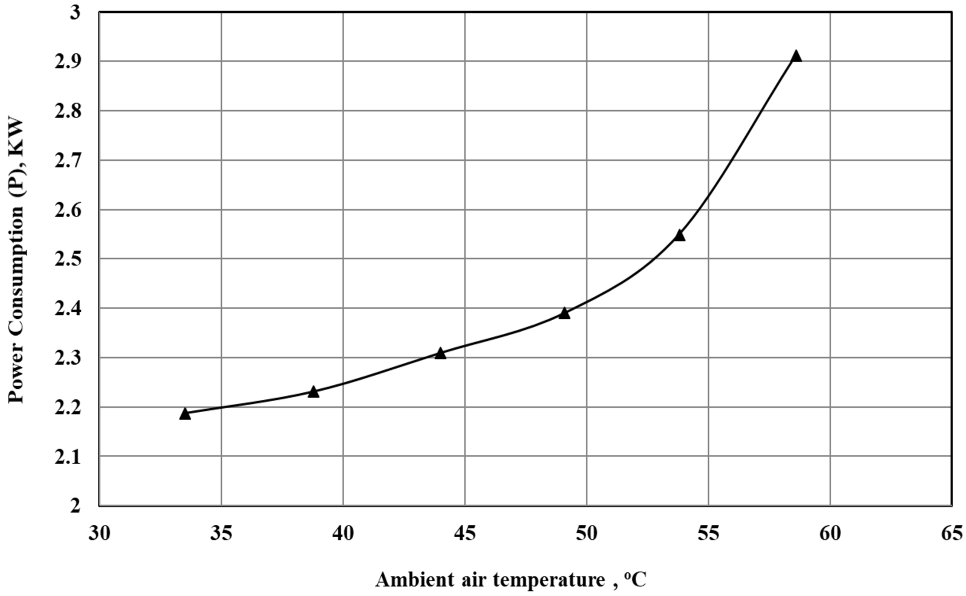

Figure 5: Impact of the ambient air temperature on the total power consumption (P)

The effect of the ambient air temperature on the coefficient of performance (C.O.P) of the split-air conditioning system is the major and very important parameter of this study as it reflects the whole performance of the air conditioning unit. Figure 6 illustrates the effect of ambient air temperature on the coefficient of performance (C.O.P) of the system. It is noticed that the coefficient of performance decreases with increasing the ambient air temperature. Increasing the ambient air temperature from 33 ^{0}C to 59 ^{0}C, decreases the coefficient of performance (C.O.P) of the split-air conditioner by 26%.

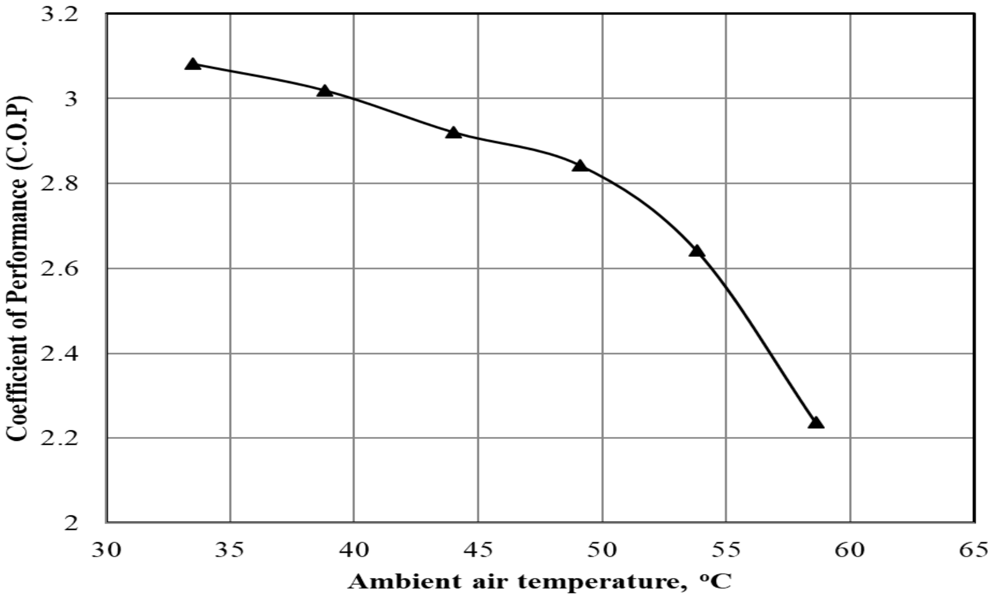

Figure 6: Impact of the ambient air temperature on the coefficient of performance (C.O.P).

Conclusions

The present investigation is dedicated to evaluate the impact of the ambient air temperature on the thermal performance of the split air-conditioning system and the main conclusions are summarized below:

- Increasing the ambient air temperature from nearly 33 to 50 ^{0}C leads to decreasing the temperature difference across the condenser (ΔT_{cond}) by 77 % while more increasing in ambient air temperature up to 59 ^{0}C reduces the ΔT_{cond} by 10 %.

- Increasing the ambient air temperature from 33 to 59 ^{0}C, increases the condenser temperature (T_c) by nearly 34%.
- Increasing the ambient air temperature from 33 to 59 ^{0}C leads to increasing the power consumption by 33%.
- Increasing the ambient air temperature from 33 to 59 ^{0}C, decreases the coefficient of performance (C.O.P) of the split-air conditioner by 26%.

Nomenclature

C.O.P	coefficient of performance (–)
$\dot{Q}$	heat transfer rate (kW)
$\dot{m}$	mass flow rate (kg/s)
h	enthalpy (kJ/kg)
T	temperature (^{0}C)
P	power (kW)
p	pressure (kPa)

Greek letters

η	efficiency (%)

Subscripts

comp	compressor
cond	condenser
ele	electrical
evap	evaporator
ise	isentropic
mech	mechanical
R	refrigerant
t	total

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