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Energy conservation studies on a split airconditioner using loop heat pipes

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ABSTRACT

An experimental work was conducted to observe the effects of incorporation of Loop Heat Pipes on energy consumption and dehumidification in a split Air Conditioning system. In this investigation, three Loop Heat Pipe units were fabricated and filled with Ethanol as working medium and incorporated with the cooling coil of a split air conditioning system. Under the normal design indoor temperature range of 22–26 °C and 50% RH, when three number of Loop Heat Pipes units are incorporated in the air conditioning unit, keeping air flow rate constant, the improvement in Coefficient of Performance (COP) is found to be 18–20%. Also found that the Apparatus Dew Point (ADP) dips to 8.9 °C from 11.8 °C, the supply air Dry Bulb Temperature (DBT) increased from 11.8 °C to 16.3 °C and the dehumidification capability of the air conditioning system enhanced by 30%. The cooling capacity improvement index α is found to be 23.5%. The latent heat recovery is found to be 482W When 3 number of Loop Heat Pipe units are employed. The investigation implies that the Loop Heat Pipe units employed in the split air conditioning system not only substantially reduces the energy requirement and can improve the moisture removal capability of the air conditioning system

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1. Introduction

With the rapid development of the economics and the consequent improvement on the living standards of common man in developing countries, the usage of air conditioning equipment has been increasing faster in the recent years. The effect of air conditioning demand makes the energy consumption increasing quickly and also the energy cost. Around 15% of global energy utilization is towards air conditioning and refrigeration. Incorporation of Loop Heat Pipes (LHPs) in domestic air conditioning system is one of the techniques to make the system energy efficient and affordable. In our present research 3 number of LHPs were fabricated and incorporated in the cooling coil of the (Air Conditioner) AC unit and its effects are studied on the return air, the supply air, the cooling coil capacity and the moisture removal capability using TEMPTROL Psychrometric analysis software for different supply and return conditions of air.

2. The literature study related to the research

Split air conditioning systems play a major role in air conditioning requirements of domestic and commercial buildings. The air leaving the cooling coils of these conventional systems is moist with relative humidity (RH) of about 90–95% and of too low temperature to be used directly in the occupancy area. Xiao Ping Wu et al. [1] have reported that if the RH level in dwelling space is higher than 70%, a disease called Legionella could breakout. ASHRAE Standard 62-1989 stipulates that optimum RH level of 30–60% in living spaces to prevent the growth of algae and mould. To address this issue, a Loop Heat Pipe (LHP) can be incorporated in a split AC unit's cooling coil for the twin purposes of recovering heat from the return air and to reheat the low temperature supply air to minimize reheating energy. The evaporator of the LHP works as pre cooler for the return air before it passes through the evaporator coil and reduces the compressor's heat load.

Several studies have been carried out on employment of Heat Pipe Heat Exchanger (HPHX) in AC systems to conserve energy. Yau et al. [2] report that, though the horizontal and vertical configurations of HPHX are implemented in sub tropical climates for recovery of coolness, dehumidification purposes and to maintain better indoor air quality standards, the benefits of the same are yet

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Nomenclature

L	*heat pipe length (m)*
m	*mass flow rate of air(kg s^{-1})*
p	*pressure (Pa)*
Q	*heat transferred (W)*
w	*humidity ratio, kg/kg of dry air*
T	*temperature (K)*
V	*volume (m^3)*
W	*compressor work (kJ)*
h	*enthalpy, (kJ kg^{-1})*
P	Power (kW)
R	Return condition
S	Supply condition
T_s	Saturation temperature (K)

Subscripts

a	Air
S	Supply condition of air
rh	Reheating
pc	Pre cooling
lh	Latent heat
c	Compressor
sh	Sensible heat
lh	Latent heat
cc	Cooling coil

Acronyms

RH	Relative humidity
RSHF	Room sensible heat factor
LHP	Loop heat pipe
AC	Air conditioner
COP	Coefficient of performance
DBT	Dry bulb temperature
ADP	Apparatus dew point
CON	Conventional
SHF	Sensible heat factor
EER	Enery efficiency ratio
EBR	Energy balance ratio
HVAC	Heating ventilating air conditioning

to be familiarized in the tropical countries like Malaysia and other Middle East countries.

Guo et al. [3] have reported in their study that at a constant air state of 28.5 °C and 60% RH, when more number of Pump Assisted Seperate Heat Pipes (PASHPs) are added in the air handling coil the supply air temperature would be higher and the apparatus dew point temperature would be lesser. Also they have reported that the humidity removal capacity of the system had been improved by 29.5%. They concluded that the incorporation of PASHPs can significantly slashes the running cost of air conditioning systems. In his study on optimization the heat pipe geometry for effective natural cooling, Hassam Nasarullah Chaudhry [4] predicted the air flow pattern and temperature profile pattern for a built environment using Computational Fluid Dynamics (CFD) and validated his findings experimentally with wind tunnel.

With refrigerants R134a and R22 as working media, the performance of the air conditioning unit with Closed Loop Oscillating Heat Pipes with Check Valves (CLOHP/CV) was conducted and compared with the conventional air conditioner by Suprirattanakul et al. [5]. They concluded that the capacity of cooling coil, the COP and the EER improved by 3.6%, 14.9% and 17.6% respectively. Haitao Wang et al. [6] have proposed a secondary heat recovery on a heat pipe air conditioning system, which uses Heat Pipe Heat Exchanger (HPHE). They carried out a theoretical case study taking Hefei city (China) as a reference and analysed energy consumption between a secondary heat recovery HPHE AC system and a common heat recovery HPHE AC system. They concluded that an average heat recovery efficiency of 21.08% in winter and 39.2% in summer. For the given indoor conditions, Wan et al. [7] have reported 23.5–25.7% rate of energy saving in their work on energy conservation analysis on a central AC system employing HPHX.

Etheridge et al. [8] have studied the effect of incorporation of Phase Change Material/HPHX (PCM/HPHX) on reducing air conditioning heat loads of buildings. They have concluded that the objective of their work was to incorporate the above cooling system in the existing air conditioning equipments to reduce energy consumption and environment pollution. Khanh Dinh [9] has invented a serpentine heat pipe and reported its application in dehumidification through patent number US5845702. In his discovery, he connected several heat pipes with U bends to form a continuous heat pipe with integral condenser and evaporator portions to form a single section heat exchanger. He claimd that these types of heat pipe are superior in dehumidification than the conventional heat pipes. An enhanced effectiveness was reported by Mostafa et al. [10] in their investigation on employability of HPHX for energy recovery from AC units.

Yau [11] reported that the condensation formation on the evaporator section of HPHX impedes the effectiveness and also the mass transfer effect reduces the temperature difference between the supply and the return air. An experimental study by him showed that the inclination of HPHX had no impact on their thermal performance. Guiyin Fang et al. [12] have studied the effects of Separate Heat Pipes(SHP) on ice storage AC systems. Cool Thermal Energy Storage (CTES) can make significant energy savings by effective grid demand management. On investigation of several parameters of the AC system they reported that the ice storage AC system worked steady and stably during charging and discharging cycles. A case study on prediction of energy saving to the level of 6794 kWh,1278 kWh and 14132 kWh was reported by Ahmadzadehtalatapeh et al. [13] upon employing HPHX in AC systems, considering Kuala Lampur city as reference for the respective years of 2000,2020 and 2050. They also reported reduced SHR to the tune of 0.188. An increased heat transfer rate due to enhanced return of working medium to the condenser side in the rotating HPHX was reported by Yau et al. [14]. Their study on thermal performance characteristics of different working media was reported employing Rotating Heat Pipes (RHP). For the set face velocity and return air condition, the incorporation different configurations of HPHX in HVAC system and their performance in energy recovery was simulated and experimentally compared by Yat H.Yau et al. [15]

An experimental work was reported by Sheik Ismail tharves mohideen et al. [16] by incorporating Wick less Loop Heat Pipes (WLHP) in window AC unit to study the performance characteristics like COP, energy conservation and humidity collection. They incorporate the WLHPs at the cooling coil of the window AC unit. They report that due to energy recovery effects of WLHPs, the COP and humidity collection have been enhanced by 18–20% and 35% respectively. They also reported 20–25% reduction in energy consumption. Hussam jouhara et al. [17] experimented with a bundle of 7 finned loop heat pipes to test the effects of heat load and the air velocity on their thermal resistance. Michael K. West et al. [18] reported that ASHRAE standard 90.1.2010 stipulates effective ventilation with fresh air in the dwelling spaces. His study on Dedicated Out side Air Conditioning system (DOAS) explores the potential of employing heat pipes for eliminating the conventional reheating of supply air.

Richard Meskimmon [19] has published an informatory note that unlike in the conventional ventilation technique, where the fresh air and return air mixture is supplied at a temperature of

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