A Review on Energy Saving in Air Condition Structure By Means of Heat Pipe Heat Exchanger (HPHX)

B. Laxman[*1], Dr. Mohd Mohinoddin[2], Dr. Narsimhulu Sanke[3]

[*1]Research Scholar, Mechanical Engineering Department, University College of Engineering (A), Osmania University, Hyderabad, Telangana.
[2]Professor, Mechanical Engineering Department, Muffakham Jah College of Engineering and Technology, Hyderabad, Telangana.
[3]Professor, Mechanical Engineering Department, University College of Engineering (A), Osmania University, Hyderabad, Telangana.

Abstract

Heat pipes are widely used in industries like food, electronics, space technology, and air conditioning. The current research conducts a literature review on heat pipe for air conditioning applications. This paper focuses on the heat pipe heat exchangers used for sensible heat recovery and dehumidification enhancing features for an air conditioning application. Based on the results of this study, it is advised that heat pipe heat exchangers be applied to traditional air conditioning systems as a reliable way to reduce energy consumption, while maintaining livable room conditions. This study provides an overview of the many parameters and techniques that are applied to improve efficiency of Air conditioner.

Keywords: *Heat pipe heat exchanger (HPHX), heat ventilation and Air conditioning (HVAC), Efficiency*

1. Introduction

Most of the energy needed to maintain a comfortable indoor environment in a building comes from the heating, ventilation, and air conditioning (HVAC) system [1]-[4]. This system is essential for maintaining a comfortable indoor climate regardless of the weather outside. Heating, ventilation, and air conditioning (HVAC) systems' performance have traditionally been evaluated using the coefficient of performance (COP) [5] - [7]. The COP is ratio of electrical energy input to cooling/heating energy performance. A higher COP indicates a more efficient HVAC system that uses less energy. Carnot's Theorem [5] states that a cooling system's COP is determined by the temperature differential between the indoors and outdoors. The purpose of HVAC is to maintain a comfortable indoor temperature throughout the cooling process. In order to increase the COP value for less energy usage and provide a comfortable environment without using too much electricity, the internal temperature can be raised to be closer to the external temperature. However, by enhancing HVAC efficiency, the total amount of energy consumed can be decreased; for this purpose, a number of methods have been adopted, one of which is the use of HPHXs.

As an effective heat exchanger, HPHXs have found widespread use in a many fields, including AC system. With the help of the latent heat of vaporisation, heat exchanger pipes are able to transmit heat over long distances with just a little variation in temperature, making them a highly efficient and useful heat exchanger. It consists of a series of sealed tubes that have been pumped with the appropriate operating fluid. During the working process, the fluid boils off to form vapor at the evaporation segment and from liquid at the other end of the tube, as seen in Fig. 1. The thermosyphon heat pipes use capillary action from the wick or gravity to transport the liquid back to the section of evaporator.

A heat pipe's exceptionally high thermal conductivity in steady state operation sets it apart from other common heat transmission technologies. Therefore, it can carry a great deal of heat across a great distance with just a little rise in temperature. Heat pipes using a liquid metallic working fluid have superior thermal conductivity to even the most efficient solid metallic conductors like silver and copper. In addition to their versatility in terms of operating temperature, heat pipes are distinguished by their ease of production and design, rapid cooling times, wide range of temperature applications, and capacity to manage and transport high heat rates.

The heat pipe has numerous benefits [9], including its easy construction, exceptional flexibility, and controllability, and its capability to transfer heat at high velocities above great distances by only a minor amount of temperature variation. According to the conducted research into the feasibility of using horizontal heat pipe heat exchangers for climate control in hot, humid weathers. Y. Yau et al. [10]. The authors reviewed theoretical and experimental research on HPHXs to determine whether or not these devices could enhance dehumidification. In order to model potential cost savings from upgrading existing HVAC systems, Mathur [11] used HPHX. Thirty-three different American cities were studied, each with its own unique climate. Potential amount of energy savings in AC by using HPHX at Pune, India were investigated by Jadhav et al [12]. Researchers looked into the relationship between the cooling coil capacity savings and the number of heat exchanger through pipes rows and it effect on operating AC system. We also looked into the relationship between the number of heat exchanger through pipes rows and the average annual energy savings in Pune. Similarly amount of energy that is consumed in a central plant AC system was studied by Wan et al. [13], who looked into the impact of a heat exchanger through pipes along with air handling coil. According to the results, adopting HPHX in central plant AC systems has the potential to greatly cut energy consumption while simultaneously increasing thermal comfort and air quality within the building.

Y.H. Yau [14] looked into the practical efficiency of HVAC units for hot and humid climates with 8 rows of thermosyphon HPHX. The effect of air velocity, relative humidity, and dry bulb temperature, on the sensible heat ratio of heat exchanger through pipes was analysed. Both M. Ahmadzadehtalatapeh and Y.H. Yau, who studied the effect of heat exchanger through pipes on energy savings in AC applications [15-17], strongly suggested using heat exchanger through pipes in this field. M. M.M. Mohammed and A. Abd El e Baky [18] looked into the possibility of using HPHXs for recovery of heat in AC systems. HPHX efficiency was studied for a variety of fresh air temperature settings and mass flow rate ratios. Di Liu et al. [19] made a distinct heat pipe to collect waste heat from an HVAC system's exhaust and also evaluated it. They used parametric analysis to determine how evaporator length, power throughput and vapour temperature affected the critical values of lower and upper bounds. The review reveals scant data on annual energy savings evaluations of HPHX-based air conditioning systems in Indian climate zones. This research looks into the feasibility of using heat exchanger through pipes for heat recovery in AC systems in various climate zones across India. Twenty-five cities across India's various climate zones are taken into account in the study.

2. Utilization of HPHXs for energy recovery

HPHXs have seen widespread use in HVAC systems and other industries since the 1970s. HVAC heat recovery can be accomplished with a wide variety of heat exchanger types. HPHXs, on the other hand, have many advantages over traditional heat exchangers, which include low running and maintenance costs as well as low initial invstment. The widespread use of HPHXs in western countries were cold climate condition are common, prompted the development of heat pipes, which expanded their applicability to environments such as the tropics.

The possibility that HPHXs may improve the dehumidification efficiency of conventional air conditioners is one of the most fascinating features of these devices. Reducing the temperature of supply air below the temperature where vapour present in changed to dew is how most air conditioners deal with humidity. The chilly air is warmed up to a temperature that can be used in the climate-controlled room. The impact of a HPHXs on the efficiency and working of a typical home AC system was experimentally investigated by McFarland et al. [20], as depicted in Fig. 2. The effectiveness of heat pipes in removing moisture from a room's air was studied, along with the auxiliary reheat needed to keep temperatures consistent and the efficiency ratio of latent energy in the AC system. With the HPHX in place, without the HPHX in place but with damping applied to restore the airflow to its original value, and without the HPHX in place but with damping applied to restore the airflow to its original value, the system was put to use in three different configurations. The HPHX improved in reduction of relative humidity 62%, increased the efficiency ratio of by 90% and decreased reheating energy requirements by 20%, and for room with dry bulb temperature of 22^0C and relative humidity of 50%. He speculated that adding HPHX to a regular AC setup could be an effective strategy for handling humidity and cutting down on reheat energy consumption.

In addition, Abd El-Baky et al [21] hypothesised that cooling of the incoming fresh air by inserting an heat exchanger through pipes between the two cricks of air conditioning (one for fresh air and the other for return air) could be beneficial. The mass flow rate was maintained in three ratios of 1, 1.5, and 2.3 between fresh air and return air were observed to verify the amount of temperature change in fresh air and heat transfer depicted in Fig 3. During the tests, the return air was maintained at 26 degrees Celsius at inlet while the input of fresh air was maintained between 32 and 40 degrees Celsius. Soylemez's [22] thermo-economic optimization method was used to calculate the optimal efficiency and compare it to the experimental findings. The temperature of the fresh air at inlet was increased to 40 degrees Celsius, and the efficiency of heat transmission for both condenser and evaporator improved by approximately 50%. Moreover, with the increase in temperature of fresh air the enthalpy ratio improved by 85%. The best outcomes were achieved at an air input temperature that was close to the working temperature of the fluid in heat pipes.

Naturally ventilated buildings also made use of horizontal high-performance heat exchangers (HPHXs). Riffat and Gan [23] looked at the efficiency of HPHXs in building which is naturally ventilated. In this work, the performance of three separate heat pipe heat recovery systems was evaluated using a two-zone chamber with a horizontal barrier. A heat pipe bank with external fins, spine fins in the shape of a cylinder, and two rows of flabbergasted heat pipes were used in the first, second, and third heat recovery systems, respectively. The units' pressure loss characteristics were calculated using a computational fluid dynamics (CFD) model. The efficiency of heat recovery units for heat pipe was found to be significantly impacted by the air velocity in the tests. Heat recovery efficiency was also shown to be improved by 16%-17% when two rows of HPHX where used along with plain fins instead of a single row operating at the same speed. The computational fluid dynamics (CFD) modelling results showed that a 2-row of line six pipes had a predicted pressure loss coefficient of 3.3 with 1m/s as the velocity, whereas the staggered pipes and the smaller heat pipes in line seven both had coefficients of 4.2 and 3.7, respectively. Without a mechanical ventilation system, the mean air speed inside a naturally ventilated low-rise building should be less than 1 m/s.

Riffat et al [24] developed a novel mathematical model for evaporative cooler by indirect means using a horizontal HXHP and porous ceramic. One is for air coming from the inside (air passage 1), while the other is for air coming from the outside (air passage 2). (air passage 2). (second air duct) Evaporation occurs in this system when heat is given to the evaporation section which is far end of the pipe in passage 1 as we can observe in Fig. 4 The produced vapour then moves to condenser section which the cooler end condenses there. The mathematical model was developed with the assumption that the flow of vapour inside HPHX is laminat and incompressible because of the relatively low velocities involved. Results showed that in dry and windy circumstances, a considerable cooling capacity could be attained. Moreover, the optimal efficiency is reached when the internal air velocity is set at around 0.6 m/s. To further increase the cooler's efficiency, it was suggested that the ceramic container and heat pipe condenser both be made more conductive.

3. Using of HPHXs in tropical and subtropical area

Multiple studies have looked at the feasibility of using HPHXs to regulate the temperature and humidity of air-conditioned areas in hot, humid climates, with the goal of meeting stringent energy management and building design standards. The HVAC unit in the hospital's sterile room must operate nonstop. Health care facilities' energy use was reduced when Hakim et al. [25] used HPHX. There were twelve heat pipes in each module of the HPHX used in the experiment. We had a disorganised line. There are three instances of a module number swap: modules 1, 2, and 3. Water is used as the working fluid in copper heat pipes with a 50% filling ratio. High-pressure, high-efficiency (HPHE) designs often use fins to increase the surface area of contact with the airflow. Beckwith [26] discussed two new applications of HPHX in Tampa, Florida's air conditioning and ventilation systems. An HPHX was shown to have beneficial effects on both operational expenses and the capacity to remove moisture. Additionally, a twist was implemented to one of the systems for saving energy consumption by recovering heat from the difference in temperature between the make-up and exhaust air flows in indirect zones inside a building, and to keep occupants comfortable by doing the same.

By pre-cooling the air, the regulated wrap-around HPHX enhanced the cooling coil's capacity to remove moisture from the air. As may be seen in Figure 5, this encircling HPHX is shown in diagrammatic form. Overcooled air, having undergone a moisture removal rate of 3.68 g/s and a cooling load of 35.2 kW without the use of HPHX, was released from the cooling coil. Since installing the HPHX, the cooling coil has been able to remove moisture at a rate of 5.25 g/s from the air and maintain a cooling load of 42.60 kW. The HPHX reduced reheat power consumption and cooling when compared with a normal reheat system, while also providing free reheat of about 7.1 kW. Using an HPHX to enhance dehumidification in an HVAC system is a similar notion that was studied by Yang [27]. The original AC system's latent cooling capacity was increased by the return air pre-cooling in the HPHX and distributing the cooling capacity.

With the help of HPHX mathematical modelling, we were able to determine the optimal level of pre-cooling for a variety of weather and HVAC load scenarios. The ratio of sensible heat to total heat was found to decrease from 0.65 to 0.6. The experimental results also showed that ability of the system to remove moisture was enhanced by 8.4%. Abtahi et al. [28] looked at the ability of HPHXs to remove moisture from the air. By routing the HPHX between the the cold supply air and heated return air, heat recovery was accomplished. By lowering the sensible cooling load, precooling increased the system's moisture removal efficiency. The analysis included thermal modelling of the entire system and of its component parts, such as the fluid loop conductance, the pipe-wick contact, and the fin-tube assembly. It was suggested that the boiling mechanism and the coefficients of heat transfer along the air side were the most important factors influencing efficiency. If the heat transfer coefficient is high enough and the liquid film is falling, the fin efficiency will be between 97% and 98%. Finally, the fin efficiency dropped to below 39% when the nucleate boiling temperature was between 1000 and 3000 w/m2 k. For the humid and hot climates for Southeastern United States, a programme was developed and simulated that can predict how well the AC system will perform using the aforementioned 2 technology. Mathur [29] looked into the possibility that a 5 tonnes AC system's efficiency could be improved by installing an heat exchanger which is used to recovery heat by natural circulation of two-phase i.e., air to air. Foreseeing the operation of a condensable air stream in a two-phase natural circulation heat recovery loop necessitated the creation of a modelling tool. The system was put through its paces in conditions reflective of the Southeasterly United. The simulation showed that a two-phase heat recovery loop in the AC system may save annual operating costs by $933.6 with average demand. It was found that the two-phase heat recovery loop could be recouped in a little over a year. Mathur [30] tried to boost the efficiency of the same system by combining two technologies: a two-phase natural circulation heat recovery loop and an evaporatively cooled condenser. A programme was written to mimic the performance of an AC unit built using the aforementioned technologies in the hot, humid climate typical of the Southeast US. The results showed that the performance of the new 5-ton air conditioning system installed in place of the old system was improved by as much as 84.4% thanks to the use of a two-phase natural circulation heat recovery loop and an evaporatively cooled condenser. We found that the combined retrofits mentioned above would pay for themselves in 0.71 years. The energy efficiency of a central air conditioning system in an office building with return air was studied by Wan et al. [31]. The results suggest that heating, ventilation, and air conditioning (HVAC) systems that use HPHX may use less energy. The office building had a cooling load reduction of 23.5-25.7% and an overall energy consumption reduction of 38.1-40.9% between an interior design temperature of 22 and 26 degrees Celsius and a relative humidity of 50%. As the targeted temperature within the building increased and the relative humidity dropped, the HPHX combined AC system became more efficient. The research suggests that an HPHX may improve indoor air quality and thermal comfort in an HVAC system while dramatically lowering energy usage. The findings showed an improvement by 84.4 % when the 5-ton old AC system was replaced by an evaporatively cooled condenser and two-phase natural circulation heat recovery loop.

4. Impact of inclination angle of HPHXs on the efficiency of tropical HVAC systems

The influence of inclination angle on HPHX operation has been the subject of a number of studies. Beckert and Herwig [32] studied the effect of inclination on the heat transfer rate of an air-to-air HPHX used in an air conditioning system. Researchers looked at how much of an incline may be applied to a set of closed, two-phase thermosyphons without significantly diminishing their heat-transfer efficiency. Overall performance is shown to be satisfactory, even when the subject is almost horizontal (up to 6 with the horizontal). It was found that the direction of total heat transfer could be changed by rotating the set of pipes by an angle of nearly 12 degrees, from -6 to +6 with regard to the horizontal. In addition, in positions 6 and +6, thermosyphon heat pipes may be utilised to pre-cool new air in the summer and heat it in the winter in an HVAC system by exchanging heat with the exhaust air and the outside channel.

To a similar extent, Said and Akash [33] compared heat pipes with and without wicks to see how tilt angle affected total heat transfer. The heat pipes were installed at 30°, 60°, and 90° angles with respect to the horizontal. In every scenario, it was found that adding wick to the heat pipe made it more efficient. Overall heat transfer coefficients for wickless heat pipes were from around 4000 to 5000 W/m2 C, while those for wicked heat pipes were in the 6500 to 7000 W/m2 C range. When wick was included into a heat pipe, the efficiency increased by about 55%, 25%, and 70% at 30, 60, and 90 degree tilts, respectively (relative to the horizontal). It was also looked into by Loh et al. [34] how the performance of three heat pipe wick topologies varied with the orientation angle. It was found that sintered powder metal heat pipes are less sensitive to gravity and heat source direction. The trials did not support placing an evaporator above a condenser in a mesh and groove heat pipe. It has also been shown by Foot et al. [35] that a plate heat pipe solar panel's efficiency is unaffected by its inclination angle. However, Guo et al. [36] found that heat pipes' efficiency may change depending on the angle at which they are angled. Each experiment was conducted in an environment where surface condensation had no role.

In very humid conditions, condensation may accumulate on the HPHXs' larger fin surfaces. Therefore, it is reasonable to assume that the efficiency of the HPHX will be diminished if condensation builds up on the fin surfaces. The effects of condensation on the fin surfaces of an HPHX under high humidity conditions on the HPHX's performance have never been reported in the literature, according to a search of the relevant databases. Researchers Kim et al. [37] studied how air input humidity affected pressure drop and heat transmission in an inverted brazed aluminium heat exchanger (Fig. 6). The heat exchanger was examined at angles of 14, 45, and 67 degrees (with respect to vertical position). The entrance air humidity was adjusted between 60% and 90% while the input temperature was held constant at 12 degrees Celsius. At inclination inclinations less than 45 degrees, heat exchangers were shown to have a little effect on heat transfer and pressure drop characteristics due to air intake humidity. In a similar vein, Yau [38] asserted that a thermosyphon HPHX operating in high humidity was unaffected by the condensate layer. Any condensate that forms on the fin surfaces of the evaporator section of a horizontally oriented design at an angle of 30 degrees should drain off more easily due to gravity. Condensation on the extended fin surfaces was thus expected to have minimal effect on the HPHX under study, leading to the HPHX being projected to be more effective than the vertical configuration. The sensible effectiveness ranged from 0.40 to 0.50 and 0.41 to 0.49 for a vertical arrangement and a slanted angle of 30 for a mass flow of 1.3 kg/m2 s and an expected evaporative relative humidity of 80%, respectively.

5. Conclusion

The literature on the use of high performance hydroxamic acids (HPHXs) in air conditioning, heating, and ventilation (HVAC) systems in tropical climates was analysed. This study reveals that HPHXs may be used in both vertical (thermosyphon) and horizontal layouts as an efficient energy recovery unit in HVAC systems for the removal of heat or coolness and for dehumidification reasons. Relative humidity is one of the top problems with comfortable indoor quality in tropical climates, yet only a small number of studies have been conducted on the use of lateral configuration HPHXs for moisture control enhancement and saving energy purposes in heating and cooling. HPHX performance in AC applications using various heat pipe wick designs has not been evaluated in a comparable manner. Furthermore, the Indian environment does not allow for the combination of HPHX and evaporative cooling. For the HVAC system to function more effectively and use less power, certain steps must be taken.

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