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Experimental Investigations of Solar Assisted Airconditioning System using Al_2O_3/ Water Nanofluid

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ABSTRACT

Air conditioning and refrigeration system consume more than 70% of the entire electricity usage in a household. These results in an increase in electricity demand on summer days. Hence, additional sources of electricity generation system such as fossil fuel and nuclear energy required to run these systems efficiently on hot summer days, which may increase the air pollution and global warming. In this paper, the solar spiral flow thermal collector is developed and integrated with the air conditioning system to reduce the power consumption of the compressor. The work done by the compressor is decreased using solar thermal collectors for heating the refrigerant R-134a contained in a double pipe arrangement with the nanofluid circulated in the outer tube. The refrigerants temperature increases due to the thermal conductivity property possessed by the Al_2O_3/water nanofluid which comprises of nanoparticles having a size less than 50nm dispersed in a base fluid of water. During this study, atmospheric temperature, the fluid temperature at the collector and the temperature at compressor were measured to investigate the COP of the system. Finally, the result shows that the satisfactory improvement of COP of the system by circulating Al_2O_3/water nanofluid compared with water.

Keywords: Solar thermal collector, Al_2O_3/water nanofluid, Coefficient of performance (COP), Refrigerant R-134a, Thermal conductivity.

I. INTRODUCTION

Due to rapid the depletion of fuels, increasing demand for energy and the environmental effects, a development of energy efficient air-conditioning system has received more attention among the researchers. In the conventional air-conditioning system, the temperature and humidity is maintained by circulating refrigerants through compressor, expansion valve, evaporator, and condenser. In this method, more energy is required to reheat and dehumidify the refrigerants. To overcome this problem, researchers were developed hybrid air-conditioning systems by including an external heater to heat the refrigerant. Various techniques and components such as flat plate and tube heat exchangers were used for this purpose [1]. Because of electrical energy demand, many researchers showed their interest on the solar-assisted air-conditioning system. Among these, The air conditioning system is powered by various sources of energy in which the PV panel cooling method is comparatively not cost effective method. There are two alternative ways to overcome this issue, to effectively cooling the air conditioning system by increasing the heat transfer characteristics of the refrigerant or increase the refrigerant temperature by an external source of heat generation.

During last decades many research articles were published related to solar-assisted air-conditioning systems. Dai et al. [2] developed a mathematical model to predict the performance of developed air-conditioning system which consists of open absorption system and vapor compression system. They observed

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that the required electrical power was reduced about 43% compared to the conventional air-conditioning system. Chen et al. [3] and Yamaguchi et al. [4] developed and analyzed the performance of hybrid air conditioning system. The performance and operating cost of the hybrid air condition system were analyzed by Capozzoli et al. [5]. These researchers were used conventional heat transfer fluid such as water to absorb the heat from the refrigerant. But the conventional heat transfer fluids possess less heat transfer coefficient. Because of this reason, a nanoparticle dispersed fluid has been used as a heat transfer fluids in modern hybrid air-conditioning systems. The first nanoparticle dispersed fluid was prepared and named as "Nanofluid" by Choi [6]. Over the past few decade, many researchers were carried out their research to investigate the thermal properties of different nanofluids [7-16]. Among other nanoparticles Al2O3 nanoparticles are having high thermal conductivity and cheap. So that in this research the Al2O3 nanoparticles are used to prepare the nanofluid.

As in the studies mentioned above, various techniques were used to improve the performance of the hybrid air-conditioning system. In this work the natural source is utilized to enhance the temperature of the refrigerant R-134a by circulating Al_2O_3/water in the double pipe heat exchanger thereby reduces the electricity consumption of the compressor.

II. NANOFLUID PREPARATION

Two glass beakers have been taken for preparation of nanofluid. The smaller glass beaker will have the solution, and the bigger beaker is meant to surround the solution with ice. For a single batch of nanofluid, measure 2wt% of Al_2O_3 nanoparticle with a spatula and place it on a butter paper and keep it on the weighing scale to accurately measure its weight. Mix the particles with a glass mixer rod in the ionized water. Before switching on the ultrasonic sonicator, clean the probe of the sonicator to avoid any involvement of foreign particles. Set the sonicator for 15 cycles 50% for a time limit of 1 hour. During the process, the ultrasonicator produces high-frequency ultrasound wave to disperse the nanoparticle into a base fluid. Finally, the SEM image is taken to study the dispersion characteristics of nanoparticle into the base fluid. Fig 1.shows the SEM image of the prepared nanofluid before and after sonication. It is absorbed that the particles are uniformly dispersed without agglomeration.

III. EXPERIMENTAL SETUP

Air conditioning systems uses a closed loop cycle. The compressor is typically used to pressurize the refrigerant (R134a) to allow the cycle to process. Alternatively, an external heat source such as a solar thermal collector used to capture the direct solar energy and impart the heat to the heat transferring fluid

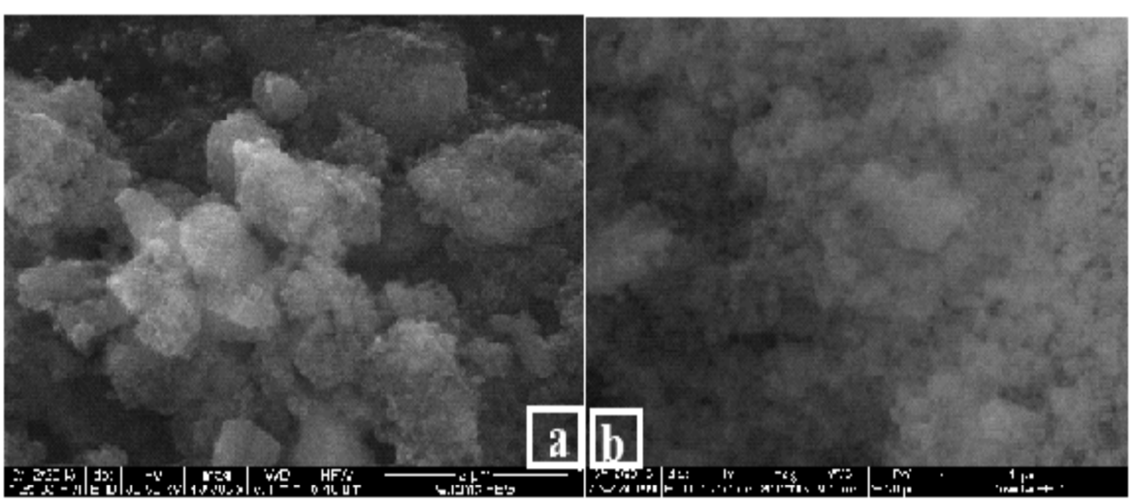


Figure 1: SEM Image of Prepared Al_2O_3/water nanofluid (a) Before sonication (b) After sonication

(Al_2O_3/water).The heated fluid transfers the thermal energy to the refrigerant (R134a) through a double pipe heat exchange thus increases the temperature and thereby increases the pressure of the refrigerant. The more heat the refrigerant is exposed to, the more time the compressor remains shut off due to the continued increases in temperature of the refrigerant, therefore reducing the run time of the compressor and eventually reducing power consumption. The solar air conditioning system has a spiral flow solar thermal collector installed adjacent to the compressor, which is used to generate the heat in the working fluid and transfer it into the refrigerant before it passing into the compressor. During this process, gradually, the pressure within the circulating refrigerant will increase and therefore increases the ability of the system to maintain the desired temperature. Contrary to this, due to the solar thermal collector system, the refrigerant continues to be pressurized from the heat being imparted into it and therefore the compressor will remain off considerably longer and saves the power consumption by the compressor. The systematic diagram and Specification of the air-conditioning system is shown in Fig. 2 and Table 1 respectively.

Table 1
Specifications of air conditioning system

Type	*Voltage*	*Frequency*	*Kcal/Hr*	*Watt*	*Btu/Hr*	*Power Consumption*	*Refrigerant*
LBP	220	50	92	107	365	96	R134a

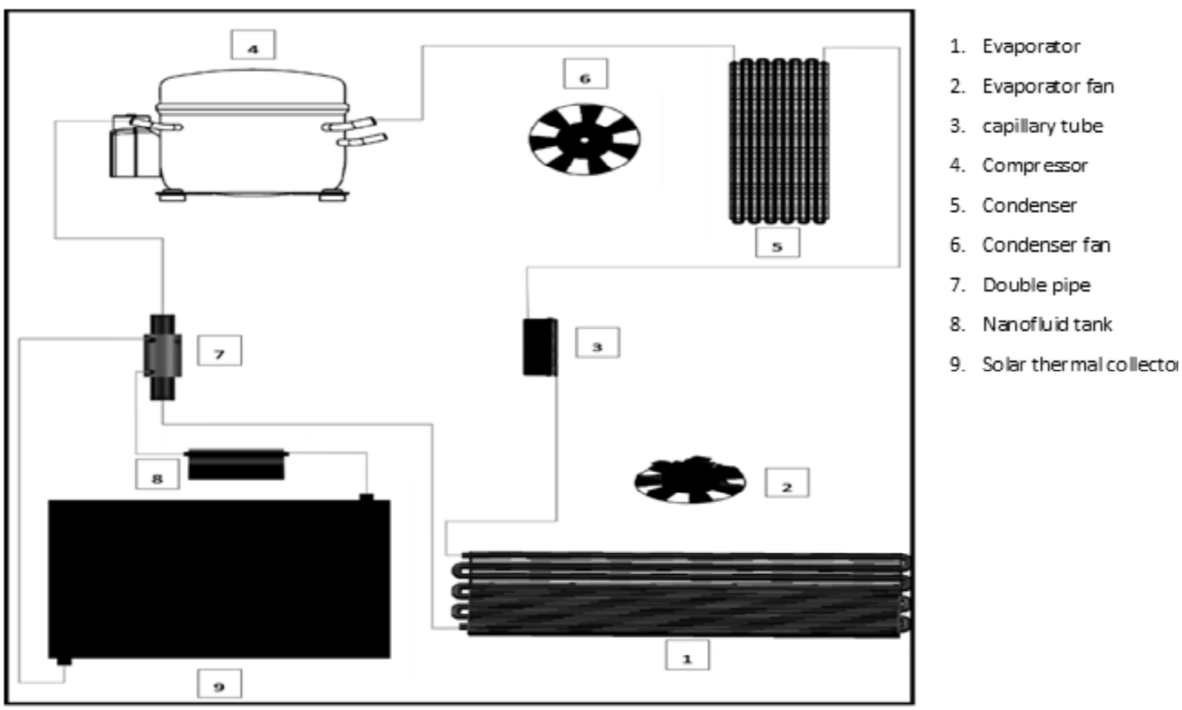


Figure 2: Schematic diagram of experimental setup

As such, the solar air conditioning system is shown in Fig. 3.consumes less electricity and, in tandem with the solar thermal collector cycle, optimizes energy savings and reduces running costs. Hence, the system saves the maximum power consumed by the home air-conditioning system.

The spiral flow thermal collector design arrangement is shown in Fig3. The copper tube diameter is 10mm, and the length is 30m sheet metal is used as a frame, and the copper tube is made as a spiral flow design which consists of 9 loops. The heat transfer fluid enters into the inlet of the tube and then the fluid gets heated due to solar radiation.

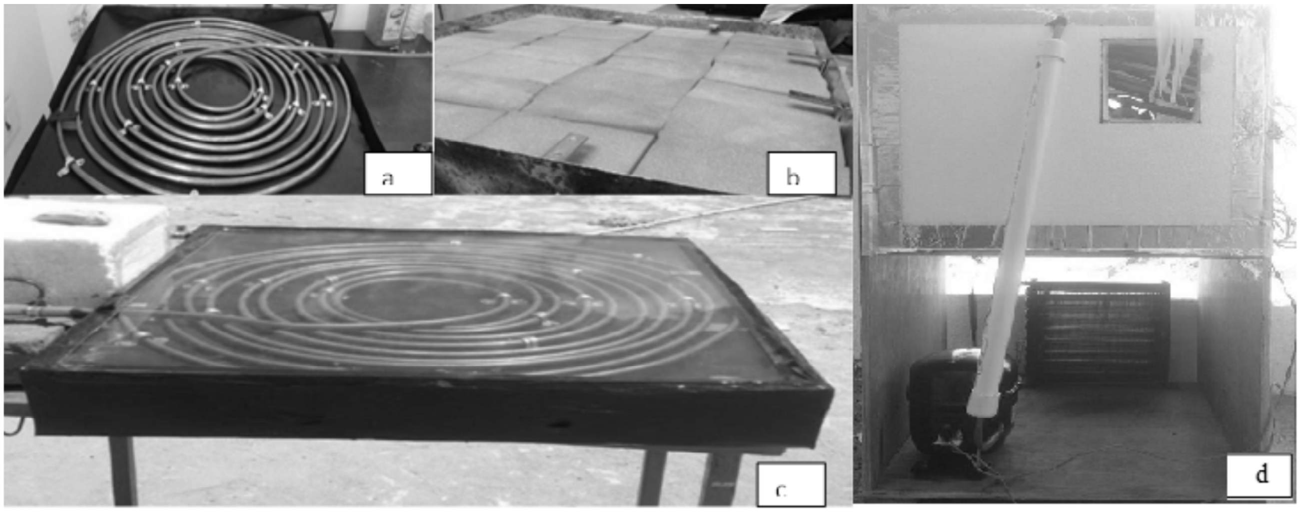


Figure 3: a. spiral flow coil b. Thermal insulation material c. Anti -reflection glass on top d. Air conditioning unit

The heated fluid from the outlet of the thermal collector is being used and transferred into the refrigerant. On the top, the anti-reflection glass was placed to absorb more incidents solar rays to increase the heat to the working fluid (Al_2O_3/water).Finally; the poly urethane material is used as a thermal insulator to minimize the heat loss.

IV. RESULTS AND DISCUSSION

The performance of the air conditioning system depends on the heat transfer capacity of the working fluid. R-134a refrigerant is used in the common home air conditioning system as a heat transfer medium. This refrigerants heat transfer capacity is not much good, and hence it increases the power consumption of the compressor. Due to this limitation, the refrigerant passes through the copper pipe which is surrounded by another copper tube that carries the (Al_2O_3/water nanofluid) heat transfer fluid. The thermal collector absorbs and converts solar radiation into useful heat energy, where Al2O3 nanofluid was circulated through double pipe heat exchanger to enhance the temperature of refrigerant before it enters into the compressor and thus reduces the power consumption of compressor.

(A) Analysis of solar thermal collector

The output temperature was measured and analyzed by circulating water and Al2O3/water nanofluid at different flow rates for 5 days. Depending upon on the readings taken, the optimum flow rate was found to be 60L/hr as it possesses the maximum heat transfer rate at an angle of inclination of 25° of the collector in the south direction. Fig 4. Shows the relationship of the collector outlet temperatures at various time intervals. It is clearly seen that the nanofluid of 2 wt % exhibits better heat transfer capacity as compared with water.

(B) Analysis of Solar Air Conditioning System

The COP (Coefficient of Performance) of the air conditioning system was analyzed in this section. Refrigerant R-134a is the working fluid in the ideal vapor-compression refrigeration cycle. The refrigerant temperatures at various stages of the cycle were measured, and their respective pressure-enthalpy values were found by using the R-134a tables. The COP is calculated by the formula:

$$COP = \frac{H_2 - H_1}{H_3 - H_2} \quad (1)$$

Where, H_1 is the enthalpy before evaporator H_2 is the enthalpy before compressor H_3 is the enthalpy after compressor

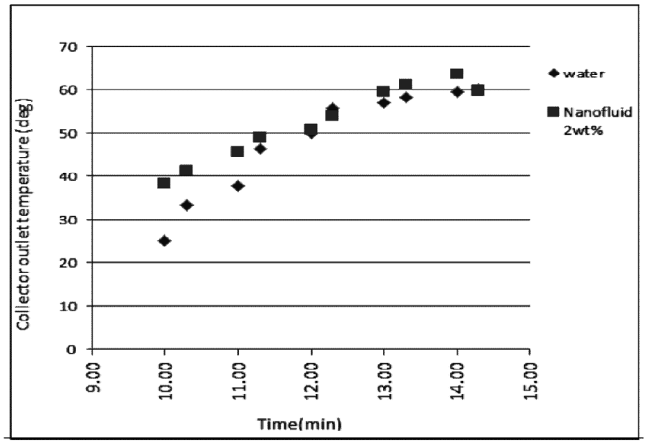


Figure 4: Collector outlet temperature Vs time

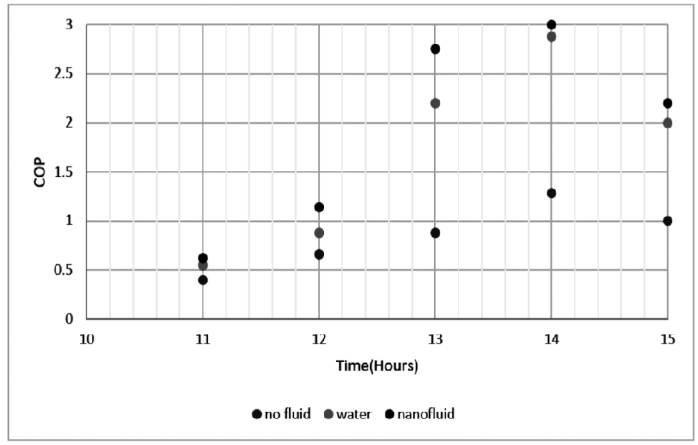


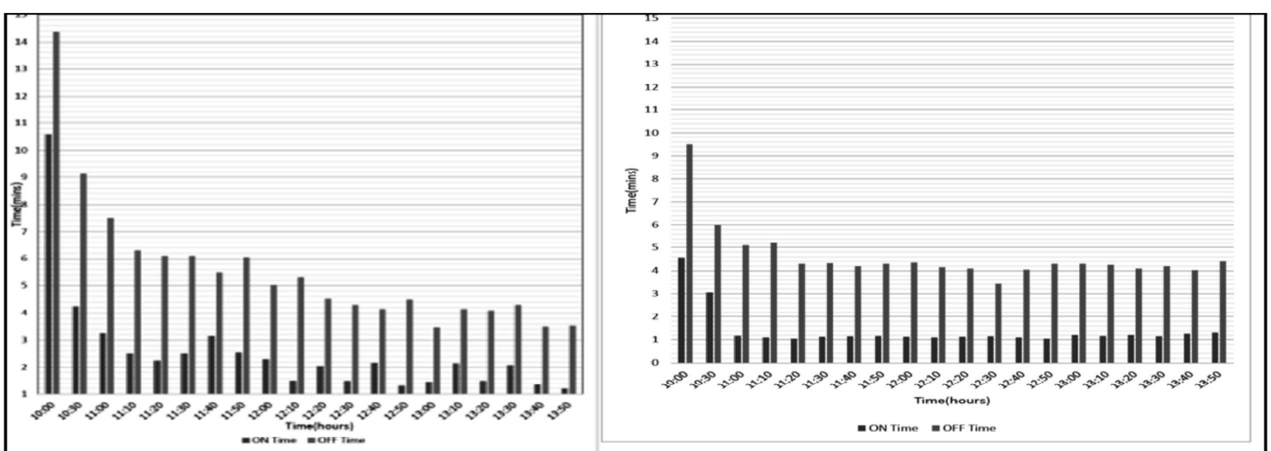
Figure 5: Coefficient of performance (COP) V_S Time

From Fig. 5, it is observed that the COP value changes with respect to time and environmental factors such as atmospheric temperature, the wind, humidity, etc. The COP calculated by using nanofluid has a higher value than the COP calculated by using water as heat exchanging fluid in the solar assisted air conditioning system.

(C) Power Consumption of Compressor

The running time of the compressor was taken for 4 hours starting from 10:00 to 14:00 with the usage of no fluid, water and nanofluid in the double pipe heat exchanger and their average run time is in Fig.6 a,b. and 7 respectively below to depict the overall efficiency of the double pipe heat exchanger. With these values, the power consumed by the compressor is calculated. When no fluid was flowing through the double pipe, the normal air conditioning cycle was operated and the running time (OFF time) increased into 14.3 min as shown in Fig. 6 a. The atmospheric temperature on that day was measured as 36°C.

When water was flowing through the double pipe, the normal air conditioning cycle was operated and the running time (OFF time) increased into 9.5 minas shown in Fig 6 b. When nanofluid was flowing through the double pipe, the normal air conditioning cycle was operated and the running time (OFF time) increases 10.5 as shown Fig. 7. The atmospheric temperature on that day was 38°C.



a.Run time of the compressor at normal operating condition

b. Run time of the compressor by ciurculating water

Figure 6: a. Run time of compressor at normal operating condition b. By circulating water

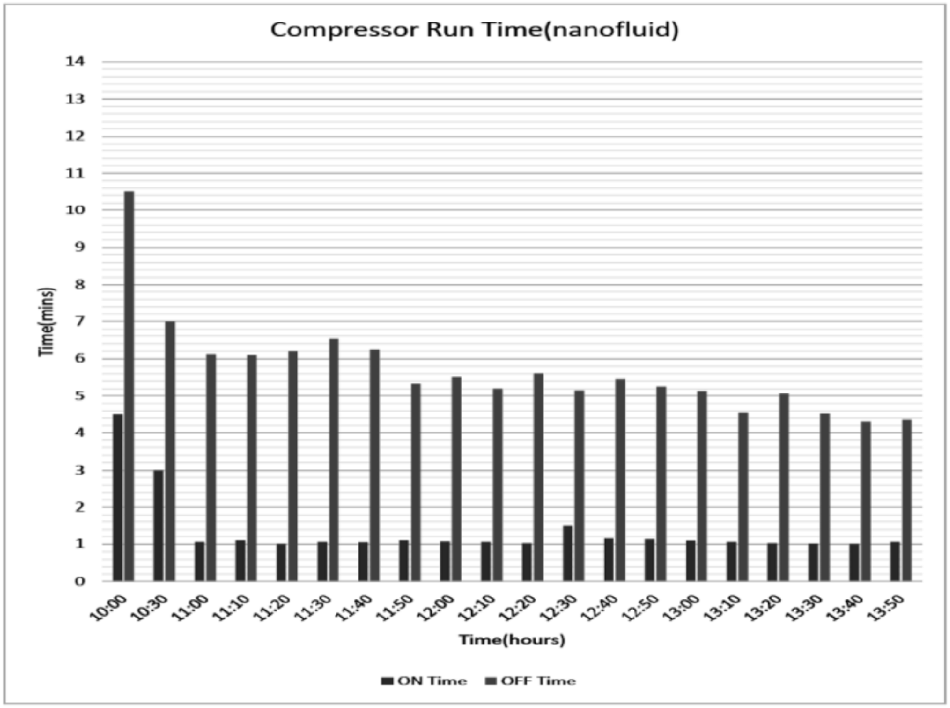


Figure 7: Run time of compressor by circulating Al_2O_3/water nanofluid

From the Fig 7.the average time has been calculated, and the values have been given in Table 2.

Table 2
Compressor runs time for water and Al_2O_3/water nanofluid

S.no.	*Atmospheric Temperature*	*Fluid*	*ON Time(mins)*	*OFF Time(mins)*
1.	36°C	No fluid	2.58	5.59
2.	40°C	Water	1.35	4.627
3.	38°C	Nanofluid	1.34	5.705

It is clearly noticed by using nanofluid as the heat transferring fluid in the double pipe heat exchanger proves to be the most efficient in reducing the average OFF time of the compressor to roughly 1 minute lesser than normal working operation.

CONCLUSIONS

In this work, the performance of the hybrid air-conditioning system was analyzed by circulating the Al_2O_3/ water in the double pipe heat exchanger thereby reduces the electricity consumption of the compressor. The conclusions of this research work were summarized as follows.

1. Solar thermal collector absorbs solar radiation and converts it into heat energy, and that heat energy is utilized for increasing the temperature of R-134a refrigerant by the exchange in the double pipe which increases the compressor's OFF time by an average of 1 minute more than the normal operating condition.
2. Al_2O_3 nanofluid was prepared using ultrasonic probe sonicator. 2wt% of the Al_2O_3 nanoparticles was suspended in the base fluid-water. By the various tests carried out with the solar thermal collector, the optimum flow rate was chosen as 60L/hr which was used during the operation of the solar assisted air conditioning system.

3. The COP of the system has been enhanced by circulating 2wt% Al_2O_3 nanofluid, and the results were compared with the COP calculated by using water which was found to be 3-4% higher on an average.

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