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Research Article

Investigation of carbon nano-tube (CNT) particles effect on the performance of a refrigeration cycle

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A b s t r a c t

In spite of previous research in Air Condition, now days because of improvement in time and cost we should apply modern technology such as nano technology in this part of science and research. In this paper, the performance and Heat transfer of a refrigeration cycle with nanoparticles in the working fluid was investigated experimentally. Water with nanoparticles mixtures were used in this experiment. The tests with carbon nano tube nanoparticles showed that the different particle volume fractions have different effect on the refrigerator performance. According to results, it is shown that increasing in CNT particles will be caused great temperature gradient in entry and discharging evaporator respect to pure water. Thus, nanoparticles can be used in refrigeration cycle to considerably increase heat transfer.

Keywords:
Refrigeration cycle, Carbon nanotube particles, Heat transfer, Performance.

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1. Introduction

Improvement of thermal conductivity of liquids was earlier made possible by mixing micronsized particles with a base fluid [1]. But, because of some problem such as rapid sedimentation, erosion, clogging and high-pressure drop caused by these particles has kept the technology far from practical use. When nano particles dispersed uniformly and suspended stably in base fluids, can provide impressive improvements in the thermal properties of base fluids. Nanofluids, which are a colloidal mixture of nanoparticles (1– 100 nm) and a base liquid (nanoparticle fluid suspensions) are the term first coined by Choi in the year 1995 [2] at the Argonne National Laboratory. Nanoparticles Compared to micron-sized particles, are engineered to have larger relative surface areas, less particle momentum, high mobility, better suspension stability than micron-sized particles and importantly increase the thermal conductivity of the mixture. Nano fluids are favorable working fluids in medium as coolants, lubricants, hydraulic and metal cutting. Further, a negligible pressure drop and mechanical abrasion makes researchers subscribe to nanofluids for the development of the next generation miniaturized heat exchangers. Based on where we want to use, nanoparticles have been made of various materials [3–17] such as oxide ceramics, nitride ceramics, carbide ceramics, metals, semiconductors, carbon nanotubes and composite materials.

2. Basic Refrigeration Cycle

Refrigeration is a process in which work is done to move heat from one location to another. The work of heat transport is traditionally driven by mechanical work, but can also be driven by heat, magnetism, electricity, laser, or other means. Refrigeration has many applications, including, but not limited to: household refrigerators, industrial freezers, cryogenics, and air conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to refrigeration units. Although the entire chiller package is more complex, the basic components required for mechanical refrigeration are the compressor, evaporator, condenser and thermostatic expansion valve.

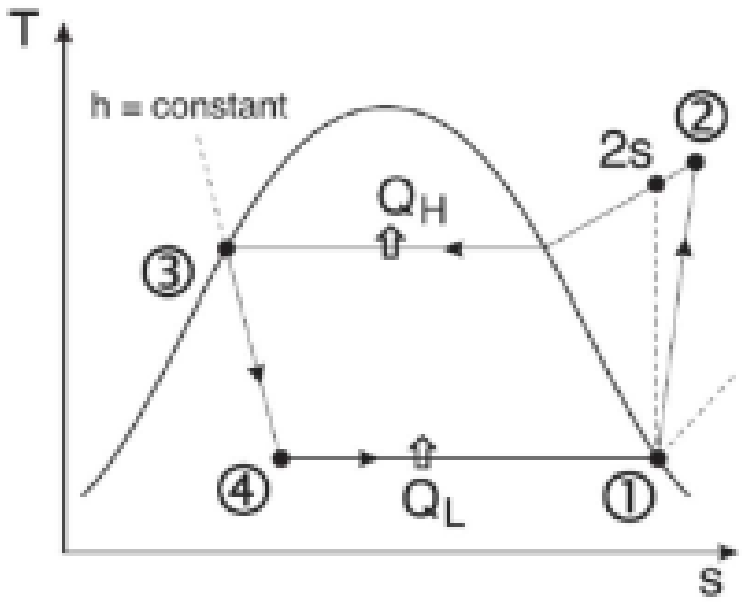

Fig. 1: T-s diagram of refrigeration cycle.

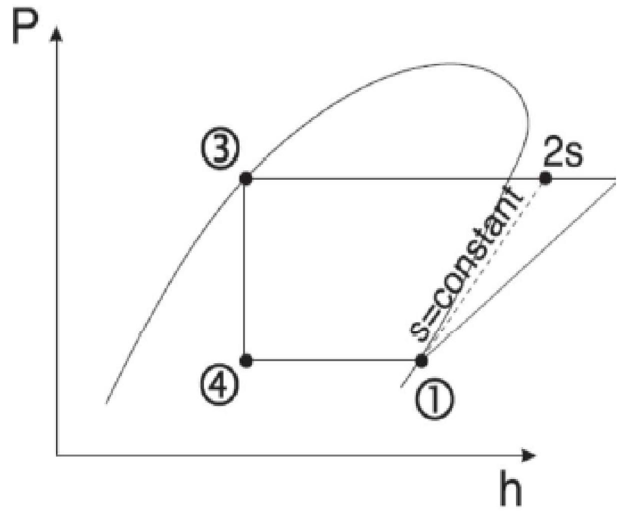

Fig. 2: P-h diagram of refrigeration cycle.

Table 1: Refrigeration process

Process	Description
1-2s	A reversible, adiabatic (isentropic) compression of the refrigerant. The saturated vapor at state 1 is superheated to state 2. $\Rightarrow W_c = h_{2s} - h_1$ (1)
2s-3	An internally, reversible, constant pressure heat rejection in which the working substance is desuperheated and then condensed to a saturated liquid at 3. During his process, the working substance rejects most of its energy to the condenser cooling water. $\Rightarrow q_h = h_{2s} - h_2$ (2)
3-4	An irreversible throttling process in which the temperature and pressure decrease at constant enthalpy. $\Rightarrow h_3 = h_4$ (3)
4-1	An internally, reversible, constant pressure heat interaction in which the working fluid is evaporated to a saturated vapor at state point 1. The latent enthalpy necessary for evaporation is supplied by the refrigerated space surrounding the evaporator. The amount of heat transferred to the working fluid in the evaporator is called the refrigeration load.

$$\Rightarrow q_1 = h_1 - h_4 \qquad (4)$$

The thermal efficiency of the cycle can be calculated as:

$$\eta = \frac{q_{evap}}{w_{comp}} = \frac{h_1 - h_4}{h_{2s} - h_1} \qquad (5)$$

3. Preparation and properties of nanofluid

Multi-walled carbon nanotubes (MWCNT) were prepared from Research Institute of Petroleum Industry (R.I.P.I.) with 90–95% purity were dispersed in distilled water, as the base fluid, to form the CNT–water nanofluids. The average diameter of the nanotubes varies from 10 to 20 nm and their length from 5 to 15 μn. The nanofluids were synthesized by the two-step method, without any surfactant in order to not affect the viscosity and the thermal conductivity of suspensions. Favorable volume fraction of CNT-water nanofluid was prepared by mixing appropriate quantities of nanoparticles with the water, and then sonicated by an ultrasonic bath (Hielscher UP400S, H40sonotrode) for at least 100 min. The CNT nanofluid used in this study stayed stable for a period of 60h without any visible settlement.

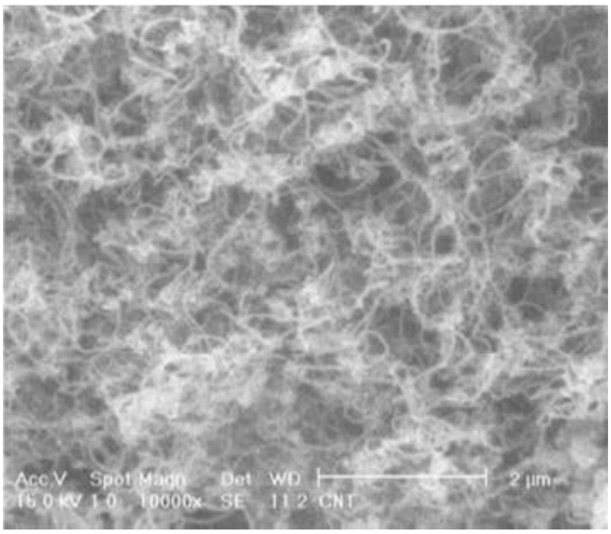

Fig. 3: Typical SEM image of carbon nanotubes.

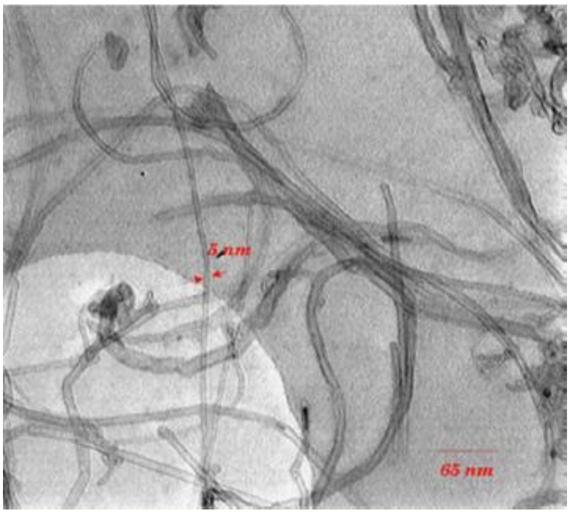

Fig. 4: Typical TEM image of carbon nanotubes.

4. Experimental procedure

The refrigeration cycle performance was first measured using pure water as the working fluid for base data. Then, pure water with various mass fractions of CNT particles were used as the working fluid for the same tests. Finally, we compare heat transfer in two different conditions and it was shown the effect of nanoparticles on the refrigeration cycle performance clearly.

5. Experimental apparatus

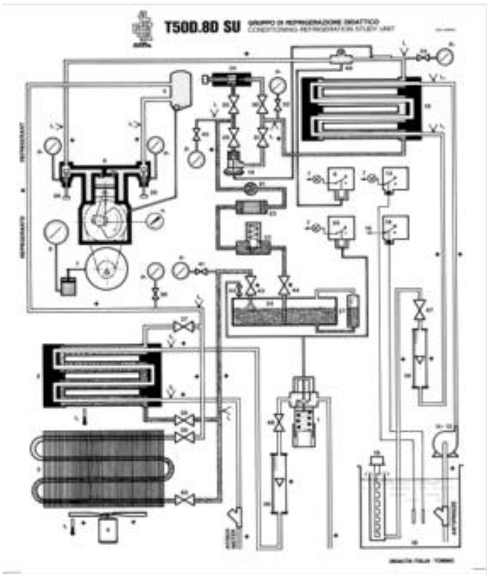

Fig. 5: Schematic of the experimental setup.

6. Discussion and results

The refrigeration cycle heat transfer results with pure water were compared to water and CNT particles mixture. According to below figures, It is shown that increasing in CNT particles will be caused great temperature gradient in entry and discharging evaporator respect to pure water. for example in t=592(s), evaporator entry pure water temperature is 10.1($℃$) wheras evaporator entry water/CNT 2000 ppm mixture temperature is 10.8($℃$) and evaporator discharging pure water temperature is 7.6($℃$) wheras evaporator discharging water/CNT 2000 ppm mixture temperature is 6.5($℃$), therefore temperature gradient changes from 2.5($℃$) in pure water to 4.3($℃$) in water/CNT 2000 ppm mixture, then temperature increasing results heat transfer increasing. Because of the performance of the cycle has a direct relation with heat transfer in evaporator according to equ.(5), then, mixing of CNT particles with pure water causes increasing in performance of refrigeration cycle. Because of the importance of refrigeration systems in industry, it is suggested using of water/CNT particles mixture as based fluid in refrigeration systems. The main experimental results are shown in tables 2 to 4 and figures 6 to 9. Every test was run 3–5 times at the same conditions to ensure repeatability.

Table 2: Evaporator entry temperature in pure water and different amount of CNT

t(s)	T($℃$) Pure water	T($℃$) 150 ppm	T ($℃$) 300 ppm	T ($℃$) 600 ppm	T ($℃$) 900 ppm	T ($℃$) 2000 ppm
0	14.9	14.9	14.9	14.9	14.9	14.9
70	14.1	14.1	14	14	14.1	14
130	13.4	13.4	13.2	13.3	13.4	13.5
190	12.8	12.8	12.6	12.8	12.8	12.7
250	12.3	12.3	12.1	12.3	12.3	12.3
310	11.9	11.8	11.5	11.7	11.7	12
370	11.5	11.4	11.1	11.2	11.3	11.7
430	11	11	10.7	10.9	10.9	11.4
490	10.7	10.7	10.4	10.5	10.6	11.2
592	10.1	10.1	9.8	9.9	10.2	10.8

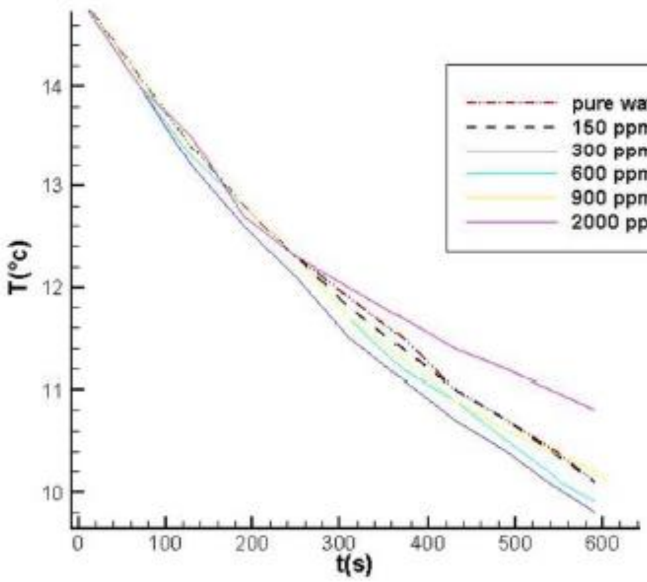

Fig. 6: Evaporator entry temperature in pure water and different amount of CNT

Table 3: Evaporator discharging temperature in pure water and different amount of CNT

t(s)	T(℃) Pure water	T(℃) 150 ppm	T (℃) 300 ppm	T (℃) 600 ppm	T (℃) 900 ppm	T (℃) 2000 ppm
0	10.9	11.4	11.1	11.3	11	11
70	10.3	10.8	10.4	10.5	10.4	9.8
130	9.9	10.2	9.8	10.1	9.8	9.1
190	9.4	9.9	9.4	9.6	9.5	8.5
250	9.1	9.4	8.9	9.3	9.2	8.2
310	8.7	9	8.5	8.9	8.7	7.8
370	8.4	8.7	8.2	8.5	8.3	7.4
430	8.1	8.4	7.9	8.1	8.1	7.2
490	7.8	8	7.6	7.8	7.9	7
592	7.6	7.6	7.1	7.4	7.5	6.5

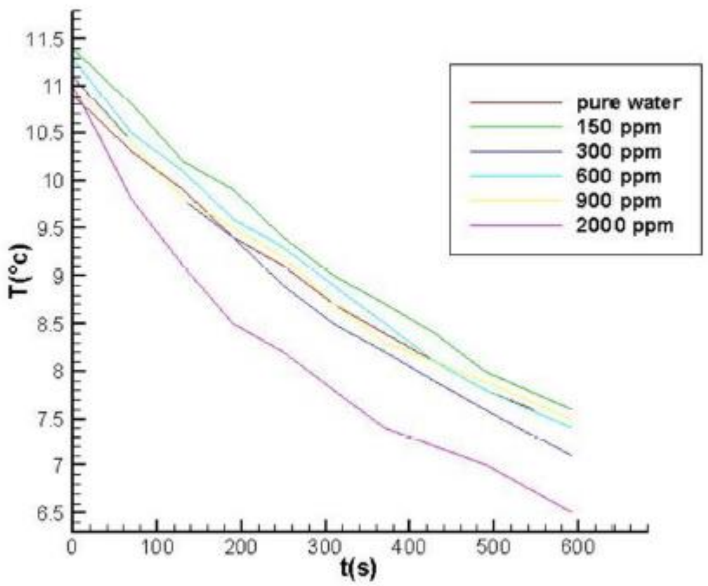

Fig.7: Evaporator discharging temperature in pure water and different amount CNT

Table 4: Evaporator entry and discharging temperature gradient.

t(s)	T (℃) Pure water	T (℃) 150 ppm	T (℃) 300 ppm	T (℃) 600 ppm	T (℃) 900 ppm	T (℃) 2000 ppm
0	4	3.5	3.8	3.6	3.9	3.9
70	3.8	3.3	3.6	3.5	3.7	4.2
130	3.5	3.2	3.4	3.2	3.6	4.4
190	3.4	2.9	3.2	3.2	3.3	4.2
250	3.2	2.9	3.2	3	3.1	4.1
310	3.2	2.8	3	2.8	3	4.2
370	3.1	2.7	2.9	2.7	3	4.3
430	2.9	2.6	2.8	2.8	2.8	4.2
490	2.9	2.7	2.8	2.7	2.7	4.2
592	2.5	2.5	2.7	2.5	2.7	4.3

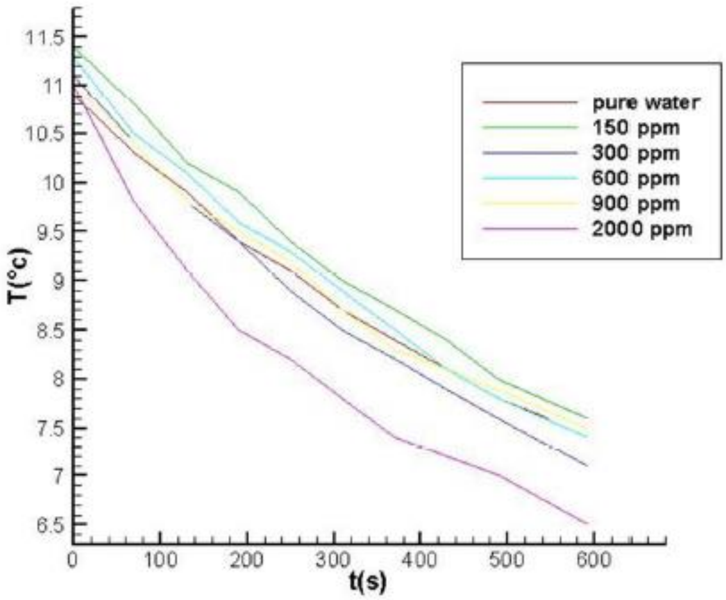

Fig. 8: Evaporator discharging temperature in pure water and different amount of CNT

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