Use AL_2O_3 Alumina Nano-fluid for Enhancement Heat Exchangers Performance

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Abstract

A nano-fluid is a fluid contains nano- particles with particle size less than 100 nm dispersed in base fluid. In this work nano- alumina fluid was formulated at different concentration (0.1, 0.3,0.5,1 and 2 wt % AL_2O_3) in soft water solution. A glassy heat exchanger system was built to study the effect of adding nano-alumina solution on the efficiency of heat exchanger by measuring the value of thermal conductivity theoretically and practically, the results showed enhancement of cooling fluid thermal conductivity to approximately three times with nano-fluids compared to water.

Key Word: Heat Exchanger, Nano-fluid and AL_2O_3

استخدام موائع نانوية الالومينا (AL_2O_3) في تحسين أداء المبادلات الحرارية

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بغداد –العراق

الخلاصة

الموائع النانوية هي موائع تحتوي على جزيئات نانوية بحجم أقل من 100 نانومتر منتشرة في مائع . في هذا البحث تم العمل على تراكيز مختلفة للموائع النانوية وهي (0.1, 0.3,0.5, 1 and 2 wt% Al_2O_3) . تم بناء منظومة مبادل حراري مختبرية من الزجاج لغرض دراسة تأثير إضافة هذه المواد على معدل انتقال الحرارة عن طريق قياس قيمة التوصيل الحراري نظريا وعمليا، والنتائج تظهر تحسن في معدل انتقال الحرارة ما يقرب من ثلاث أضعاف بوجود المائع النانوي مقارنة مع الماء.

الكلمات المفتاحية : المبادلات الحرارية ،موائع نانوية و الالومينا .

Introduction

In many heat transfer processes , heat transferred from one fluid to another through a solid wall, the heat exchanger geometry, fluid properties, and flow rat are the parameters that influence the rate of heat transfer (Holman1981). Nano-fluid are engineered colloid is made of a base fluid and nano-particles of size <100nm. Common base fluids includes water, organic liquids ,oils and lubricants bio-fluids, etc. Materials commonly used as nano-particles include chemically stable metal oxides (Alumina, Silica, Oxide Ceramics AL_2O_3, CuO) solids have thermal conductivities greater than those of conventional fluids. (Cheng, 2009).

Heat transfer can be enhanced by employing various techniques and methodologies, such as increasing either the heat transfer surface or the heat transfer coefficient between the fluid and the surface, that allow high heat transfer rates in small volume (Manglik1976) .

The addition of micrometer-or millimeter-sized solid metal or metal oxide particles to base fluids shows an increment in the thermal conductivity of resultant fluids. But the presence of mile or micronized particles in a fluid poses a number of problems. They don't from a stable solution and tend to settle down (Haghighi B.E 2005).

A part from the application in the field of heat transfer, nano-fluids (nanometer particles in fluid) can also by synthesized for unique magnetic, electrical, chemical, and biological applications they also cause erosion and clogging of the heat transfer channels(Das, *et al.*,2010).

A new technology, nano-fluid used to enhance heat transfer process (Cheng L., 2009)., showing number of patents on nano-fluid heat transfer technology and application for the energy efficiency improvement in various thermal system in recent years.

Miniaturization of electronic components has led to the demand for development of new compact heat exchanger with cooling fluid of higher heat transfer performance. The modification of thermo physical properties of coolants liquid by adding nano solid particles is the main subject of nano-fluids formulation. (Lucin and Mateescu ,2010) who studied the heat transfer in a coaxial heat exchanger using nano-fluids numerically using a computational fluid dynamics (CFD) approach. The present study indicates an increase in thermal performances about 50% with nano-fluids compared to water.

Mini heat exchanger using nano-fluid was studied by (Mapa, and Mazhar , 2005) theoretical heat transfer rates were calculated using existing relationships from literatures for conventional fluids and nano-fluids. Experiments were conducted to determine the actual heat transfer rates under operational conditions using nano-fluids and the heat transfer enhancement determined compared to fluids without nano-particles.

Shell and tube heat exchanger in their various construction modification are probably the most widespread and commonly used basic heat exchanger configuration in the industries process main reasons for this general acceptance.

The shell and tube heat exchanger provides a comparatively large ratio of heat transfer area to volume and weight(Albadr,2012).

It provides this surface in a from which is relatively easy to construct in a wide range of sizes and which is mechanically rugged enough to withstand normal shop fabrication stresses (Faragallahi 2010).

finally, good design methods exist, and expertise and shop facilities for the successful design and concentraction of shell and tube exchangers are available throughout the ward (Lienhard,2010).

The aim of this study is to prepare nano-fluids and study its effect on the coolant water thermal conductivity in the shell and tube heat exchanger at a different concentration in comparison with the base fluid (distilled water).

Materials and Methods

Experimental Set up

Fig. (1) show the schematic diagram for flow loop of constructed system . the system mainly includes two flow loop (Hot Water Flow Loop and Cold Water Flow Loop) (Farajollahi and Etemad 2010) .

It contain; a glass shell and tube heat exchanger, heating bath (5 L), cooling tank (15 L) with two pumps in order the provide required flow rates,

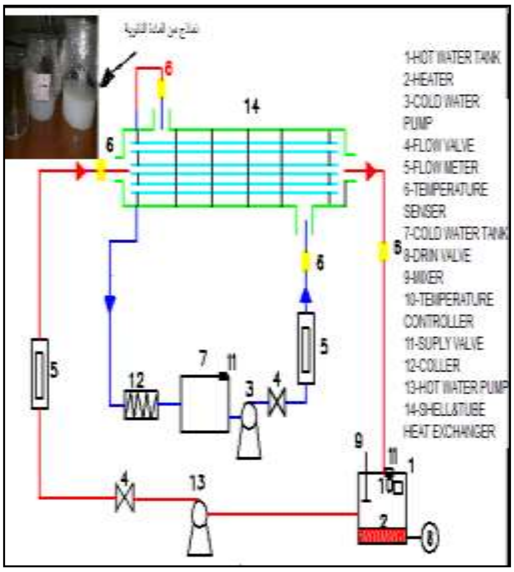


Fig. (1) Schematic Diagram of Heat Exchanger System

thermocouples, and flow meter. The flow rates are controlled by two valves shown in Fig (2) . Four thermocouples (k type) were inserted in the inlet and out let pipes of heat exchanger. Thermocouples were calibrated by glass thermometer show in Fig. (3), 1 and 2 measure the cooling water inlet and outlet from shell part of heat exchanger respectively, 3 and 4 measure the hot

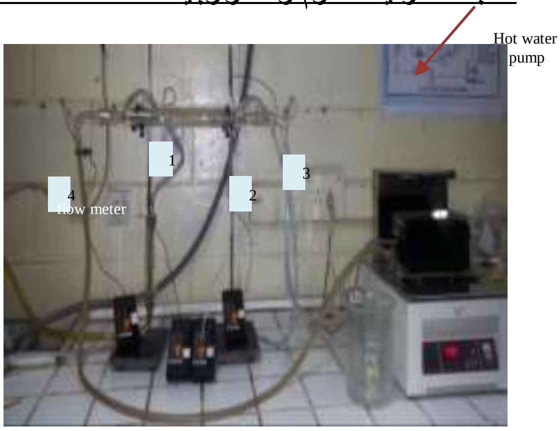


Fig. (2) Photograph Show the System of Work

water inlet and outlet water from tube part of heat exchanger respectively.

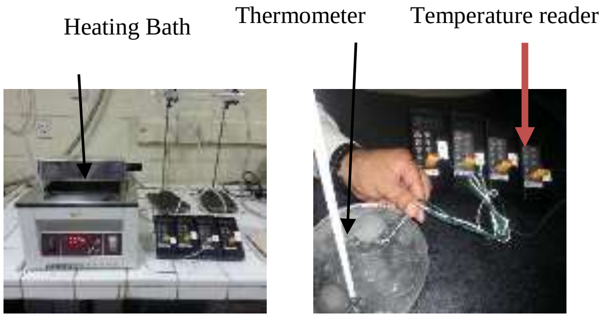


Fig. (3) Photograph Show the Calibration of Thermocouples

Preparation of Organic Alumina Sol-gel

The sol was prepared by hydrolysis of aluminum isopropoxide (Al OC_3H_3) with distilled water (molar ratio 1:9) at 85°C with stirring for one hour using magnetic stirrer, and then nitric acid was added into the solution to adjust the pH value to about 3~5. A complete hydrolysis process according to the reaction in the following equation (1) (Manna 2009).

Produced hydrated alumina oxide (Bohmite ALOOH) the concentration of alumina in the final solution was 0.25 mol \ L.

$$2[(CH_3)_2CHO]_3Al+5H_2O \longrightarrow Al_2O_3\ 2H_2O +6(CH_3)_2CHOH \quad ....(1)$$

Preparation of Nano-alumina / Water Fluid

To achieve the function of fluid thermal conductivity of variation in terms of alumina concentration, five samples were formulated by dilution of obtained sol with soft water to five dispersed alumina colloidal with 0.1, 0.3, 0.5, 1, and 2% concentration.

Results and Discussion

To understand a comparison of measurements, the experimental work divided into two parts, the first part was a measuring the accuracy of the system to work with distilled water by calculate the rate of temperature change with flow rate and without the use nano fluid as in Fig. (4) that it demonstrates the relationship between the mass flow rate of the hot water with the outside hot water temperature. The change begin to increase and then up to the critical point, that represent the quantity sufficient to cool down the system within that range of hot flow rate ($m^o{}_h$) and hot water temperature.

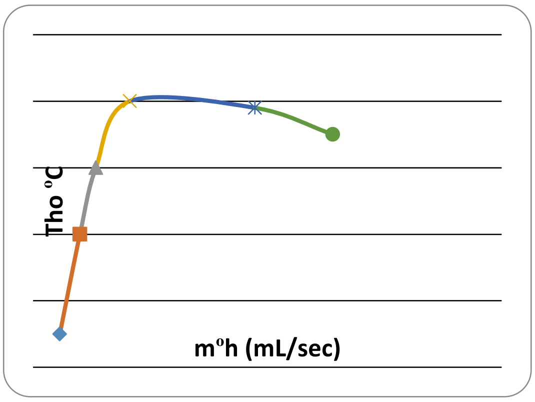


Fig (4) The Relation between Hot Distilled Water Mass Flow Rate with Outlet Hot Temperature

The second part , the measurement of thermal conductivity (theoretically) was caried out of the chemistry lab at the University of Baghdad, by using the KD2* PRo device (The KD2 Pro is a Handheld Device used to Measure Thermal Properties). It consists of a handheld controller and several sensors that operators can be used to almost any material. The single needle sensor measure thermal conductivity and resistivity; while the dual-needle sensor measure thermal conductivity, resistivity, volumetric specific heat capacity and diffusivity) Fig. (5).

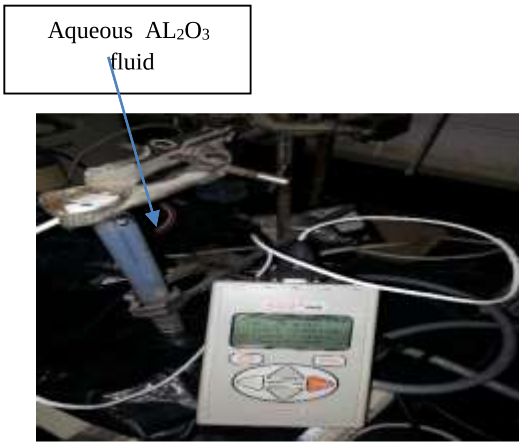


Fig. (5) Photograph Show the Thermal Conductivity Measurement for Aqueous AL_2O_3 fluid

Thermal conductivity results for different five concentrations (0.1 , 0.3 , 0.5, 1 and 2% vol.) were shown in Fig. (6) which represented the changesin the relative enhancement of thermal conductivity as function of alumina concentration . it is clear that the enhancement of thermal conductivity continue increasing with alumina concentration until 0.5 wt% to about three and two times at 0.3 wt %. The decreases of relative enhancement with concentration because the agglomeration of particles and formation clusters.

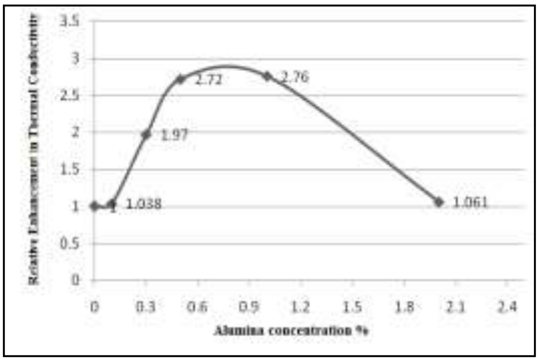
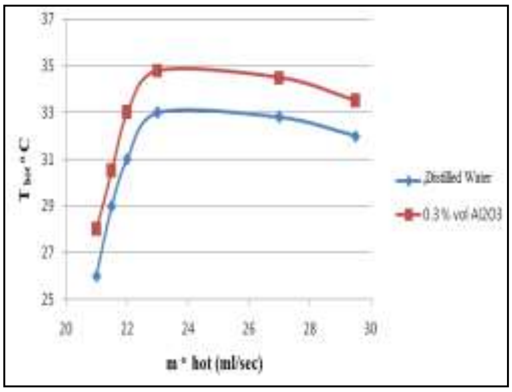


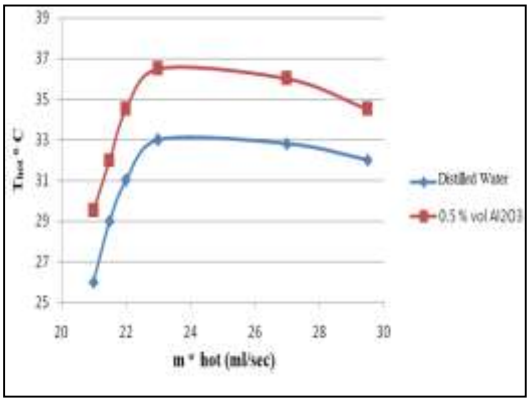
Fig.(6) Relative Enhancement of Fluid Thermal Conductivity as a Function of Alumina Concentration

In the same condition of work with adding a Aqueous AL_2O_3 nano-fluid.

Fig (7,a and 7,b) show the practical temperature change measured at the tube outlet for both max. enhancement practically (0.3 and 0.5 wt% Aqueous AL_2O_3 nano-fluid with mass flow rate. From the results of Fig (7,a and 7,b) It is clear that higher values were obtained in the case of both alumina fluid than water these increment in temperature reflected the direct effect of increasing the rate of heat transfer.



(a)



(b)

Fig. (7) Comparison between the Performance of the System with and without Solution of AL_2O_3/Water

Fig. (8) the Xerogel obtained from drying of alumina gel was shown the SEM (Scanning Electron Microscope) result ,the size of the group of nano-alumina in 5µm, the partial size distribution don by the laser diffraction analyses as shown in fig (9) at each size.

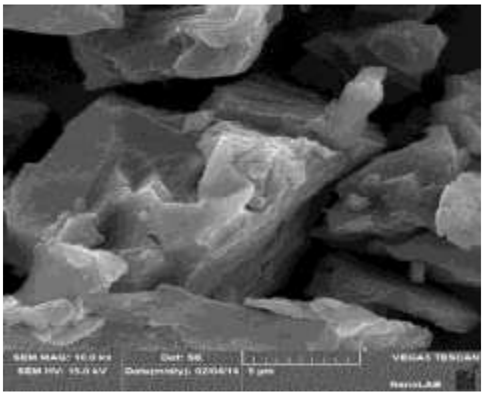


Fig.(8) Photograph Show the Xerogel Obtained from Drying of the Alumina Gel

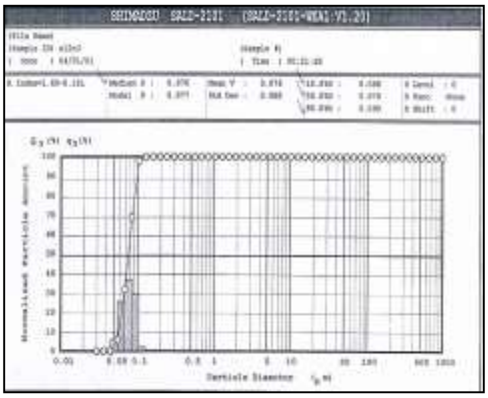


Fig (9) Laser Diffraction Analysis for the Alumina Sol. Used in Preparation of Alumina Fluid

Conclusion

The nano-scale is a broad science and needs a lot of studies and researches, its importance in adding them to the cooling fluid of heat exchangers to increase the rate of heat transfer, the results showed that the addition of nano-materials prepared in a manner Sol Gel had increased the heat value gained through increasing cooling fluid outlet temperature.

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