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Thermal Energy Storage by Nanofluids

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Abstract: Nanofluids are suspensions of nanoparticles in base fluids, a new challenge for thermal sciences provided by nanotechnology. Nanofluids have unique features different from conventional solid-liquid mixtures in which mm or μm sized particles of metals and non-metals are dispersed. At this research, adding of small weight percent of magnesium oxide (MgO) (0.1, 0.2, 0.4 and 0.5 wt.%) to pure water as working fluid in the building heating system by solar energy gave us different behavior, adding 0.1, 0.2 wt.%, gave low temperature gradient than the pure water while 0.4 and 0.5 wt.%, gave greater temperature gradient than pure water which is desired.

Key words: Nanomaterials, nanofluids, thermal energy, energy storage, Iraq

INTRODUCTION

Nanofluids are solid-liquid composite materials consisting of solid nanoparticles or nanofibers with sizes typically of 1-100 nm suspended in liquid. It has been shown that nanoparticles with higher thermal conductivity than their surrounding liquid can increase the effective thermal conductivity of suspension. For example, a small amount (<1% volume fraction) of Cu nanoparticles or carbon nanotubes dispersed in water or oil was reported to increase the inherently poor thermal conductivity of the liquid by 74 and 150% (Jana *et al*., 2007; Choi *et al*., 2001).

Nanotechnology provides new area of research to process and produce materials with average crystallite sizes below 100 nm called nanomaterials. The term, nanomaterials encompasses a wide range of materials including nanocrystalline materials, nanocomposites, carbon nanotubes and quantum dots (Gupta *et al*., 2012).

Nanofluids clearly exhibit improved thermo-physical properties, such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficient. The property change of nanofluids depends on the volumetric fraction of nanoparticles, shape and size of the nanomaterials as shown by Yang *et al*. (2005).

Heat transfer fluids have inherently low thermal conductivity that greatly limits the heat exchange efficiency. While the effectiveness of extending surfaces and redesigning heat exchange equipments to increase the heat transfer rate has reached a limit, many research activities have been carried out attempting to improve the thermal transport properties of the fluids by adding more thermally conductive solids into liquids. Liquid dispersions of nanoparticles which have been termed nanofluids, exhibit substantially higher thermal conductivities than those of the corresponding base fluids (Han, 2008).

Very high thermal conductivity and extreme stability have always been desired for heat transfer fluids with particles. Fluids having this important combination of features did not exist till the advent of nanofluids. Nanofluid technology could make the process more energy efficient and cost effective. These nanofluids could be used in a wide range of industrial applications. Demand for ultra-high-performance cooling in electronics has been increasing and conventional enhanced surface techniques have reached their limit with regard to improving heat transfer. Since, nanoparticles are relatively much smaller than the diameter of microchannel flow passages, smooth-flowing nanofluids could provide the solution. Since, nanofluids can flow in microchannels without clogging, they would be suitable coolants. These could enhance cooling of MEMS under extreme heat flux conditions (Singh, 2008).

Specific heat capacity of solvents can also be enhanced by doping with nanoparticles. Nelson *et al*. (2009) reported that the specific heat capacity of polyalphaolefin was enhanced by 50% on addition of ex-foliated graphite nanoparticles at 0.6% concentration by weight. Shin and Banerjee (2011) synthesized molten salt-based silica nanofluid and observed 26% enhanced specific heat capacity for 1% weight concentration.

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Thermal energy storage TES systems at high temperatures are required to improve the operational efficiencies and reliability of solar thermal energy conversion systems. The materials that are compatible for these applications, such as alkali-nitrates, alkalicarbonates and alkali-chlorides, as well as their eutectics have very low specific heat capacities, usually <2 J g^{-1} K while to compare, the specific heat of water is 4.2 J g^{-1} K at room temperature.

The thermal conductivity of these materials is also low, usually, 1 W m^{-1} K°. The thermophysical properties of molten salts can be improved by doping with small quantities of nanoparticles, thus realizing a high temperature nanofluid.

Direct absorption solar collectors have been proposed for a variety of applications such as water heating, however the efficiency of these collectors is limited by the absorption properties of the working fluid. Phelan *et al*. (2010) demonstrated efficiency improvements of up to 5% in solar thermal collectors by utilizing nanofluids as the absorption mechanism. The experimental and numerical results demonstrate an initial rapid increase in efficiency with volume fraction, followed by a leveling off in efficiency as volume fraction continues to increase.

In this research, researchers will find the effect of adding different quantities of nanoparticles (MgO) to pure water in the building heating system driven by solar energy on the heating loss time.

MATERIALS AND METHODS

Experimental part: An experimental investigation of the thermal energy storage by using nanofluid (adding magnesium oxide, MgO to distilled water) the size of the added particles was ranged from 20-30 nm for weight percent of 0.1, 0.2, 0.4 and 0.5 wt.%.

The system which is designed to heat building was consist of reflector which concentrates solar energy to heat the fluid passing through it, fluid storage tank to store the fluid which is circulated by using pump and solar radiator which transfer the heat into the air in the room.

RESULTS AND DISCUSION

Results were obtained for adding magnesium oxide (nanoparticles of 20-30 nm) with 0.1, 0.2, 0.4 and 0.5 wt.% to pure water in the system shown in Fig. 1.

Figure 2 shows the relationship between the temperature of the heating fluid with heat loss time, one can observe that when adding 0.1 wt.% of MgO to pure water the temperature gradient will less than the case of pure water because it will minimize the heat capacity of the whole mixture (MgO+water) while when adding 0.2 wt.% the temperature gradient will be maximized and remaining less than the pure water, after adding 0.4 wt.% the gradient will be larger than the pure water because it will prevent the heating loss and the adding of 0.5 wt.% was the greatest one, which is desired.

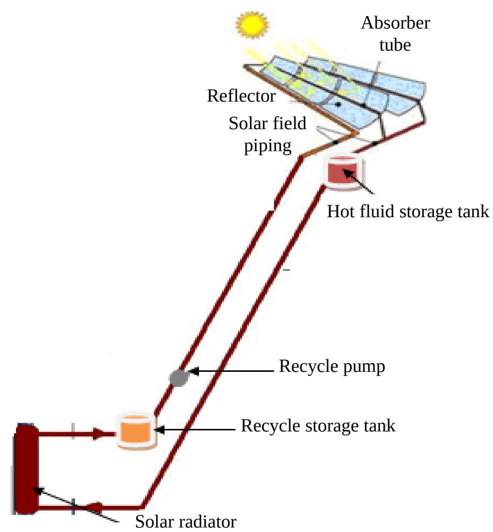

Fig. 1: Building heating system driven by solar energy

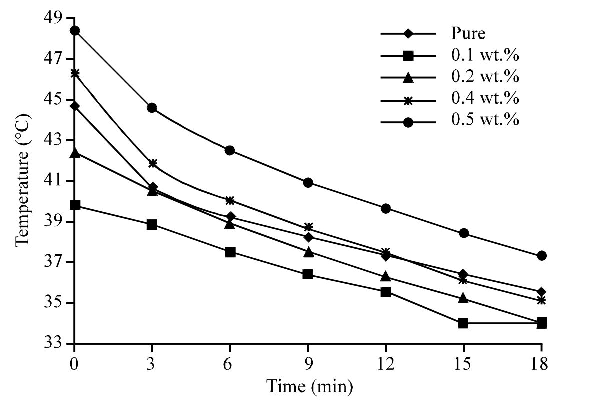

Fig. 2: Variation of temperature with time for different weights percent

CONCLUSION

From the present research, researchers can deduce these results. Adding nanoparticles (MgO) to pure water at small quantities (0.1, 0.2 wt.%) will minimize the heating loss time, also ability to heat gain is lower than pure water. Adding nanoparticles (MgO) to pure water for

(0.4 and 0.5 wt.%) will maximize the heating loss time, ability to heat gain is greater than pure water. It is possible to save energy by very small quantities of nanoparticles.

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