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A time variant investigation on optical properties of water based Al_2O_3 nanofluid ☆

M.H. Sajid [a], Z. Said [a,b,*], R. Saidur [a,b], F.R.M. Adikan [c], M.F.M. Sabri [a], N.A. Rahim [b]

[a] Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] UM Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R & D, University of Malaya, 50603 Kuala Lumpur, Malaysia
[c] Department of Electrical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

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ABSTRACT

Optical properties of nanofluids are vital for calculating performance of a Direct Absorption Solar Collector (DASC). Characteristics of nanofluids are not constant; they vary with time and growth of nanoparticles. For current investigation, nanofluids were prepared to obtain considerable stability. Stability ratio of our nanofluids was 100 times larger than the threshold limit. Here, we have investigated aggregation process and its effect on optical characteristics of the nanofluids using Transmission Electron Microscopy (TEM) imaging, Dynamic Light Scattering (DLS) approach and UV–visible spectroscopy. Steps of aggregation are broadly described with TEM images. Our results indicate that extinction coefficients of the nanofluids reduce rapidly with time within visible to near IR region. Quasi Crystalline (QC) and Rayleigh Approaches were used to compare the experimental behavior of optical properties of nanofluids. It was found that both of these approaches are weak to predict the optical behavior, especially at UV region and scattering of light is found responsible for high extinction with the experimental results. More experimental effort is still required to get an appropriate explanation.

1. Introduction

Direct absorption solar collectors have been proposed for a variety of applications, such as water heating, electricity generation and chemical processing; however, the efficiency of these collectors is limited for low efficient solar energy absorbing mediums (conventional thermal fluids). It has been illustrated that suspensions of nanoparticles (i.e., particles with diameters <100 nm), termed as nanofluids, are able to enhance system efficiency of solar collectors. Nanofluids are also found to be efficient for direct absorption solar collectors for unique optical behavior of nanoparticles [1,2]. Absorption and scattering of solar irradiation (electromagnetic wave) by particles are the main phenomenon in overall radiation energy transfer and thus proper understanding of them is crucial to predict effectiveness of nanofluids and to facilitate the development of highly efficient solar thermal collectors.

Optical properties of nano-scale materials are unique and exhibit large changes in 1–10 nm size [3]. These properties depend on size, shape, concentration, density and dielectric function of nanoparticles as well as on the properties of base mediums. Recent studies [1,2,4–15] have reported enhancement in efficiency of solar collectors using nanofluid as a heat transfer medium. Water based alumina nanofluid is also found very attractive for both direct and indirect absorption solar collectors because of its availability, low price and high efficiency. Efficiency enhancement of solar collectors is reported up to 31% with alumina nanofluid over conventional solar collector [5,7,8,10,13]. Enhancement in efficiency depends on the conditions of energy absorbers (nanoparticles). Scattering of energy carriers increases with increase in size of the particles making them low energy absorbers. Aggregation of particles is accountable for increasing size which is difficult to avoid. It is encountered even in stable nanofluids. Aggregation and stability of nanofluids solely control the unique behavior of nanofluids, no matter thermal or optical [16–18]. Hence, their effect is very important to understand and predict system performance.

Intrinsic properties (dielectric constant, refractive index, thermal conductivity, etc.) change with growth of nanoparticles, some of it affect individual particles and some affect the clusters [3]. Nanoparticles dispersed into a medium have a strong affinity to one another and for that reason they make primary clusters or groups within a short time. The stability of colloidal solution against coagulation is expressed quantitatively by the term "Stability Ratio (W)" which is defined as the ratio of the rate of diffusion-controlled and the rate of interaction-force-controlled inter-particle collisions. Diffusion-controlled collision corresponds to rapid coagulation and interaction-force-controlled collision corresponds to slow coagulation [19]. The time constant of rapid aggregation is of the order of 10^{-3} to 10 s for water-based nanofluids. W equals unity in the absence of repulsive force and hydrodynamic interaction between the nanoparticles but in the presence of the repulsive force W > 1. The threshold limit of W for diluted solution is 10^5 (for which total force, $V_{total} \sim 15k_bT$) and for very concentrated solution it is 10^9 (for which $V_{total} \sim 25k_bT$) [20]. Primary clusters come

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* Corresponding author at: Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia. Tel.: +60 3 79677611; fax: +60 3 79675317.
E-mail addresses: zaffar.ks@gmail.com, zafar@siswa.um.edu.my (Z. Said).

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