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Manuscript Submission

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Editorial Board of Journal of Engineering Physics and Thermophysics
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Dear Editor,

I am submitting a manuscript for consideration of publication in Journal of Engineering Physics and Thermophysics. The manuscript is entitled "Enhanced Heat Transfer Effectiveness Using Low Concentration SiO_2@TiO_2 Core-Shell Nanofluid in Water/Ethylene Glycol Mixture".

It has not been published elsewhere and it has not been submitted simultaneously for publication elsewhere.

This paper assesses the heat transfer performance of nanofluids containing low concentration of core-shell structure of SiO2@TiO2 nanoparticles in a mixture of water and ethylene glycol (EG) in a commercially available heat exchanger.. Its heat transfer performance written in detail explanation and equipped by graphic to help explaining the correlation between parameters. It may bring benefit to Journal of Engineering Physics and Thermophysics .

Thank you very much for your consideration, we really expect that my manuscript could be published in your journal.

Yours Sincerely,
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Enhanced Heat Transfer Effectiveness Using Low Concentration $SiO_2@TiO_2$ Core-Shell Nanofluid in Water/Ethylene Glycol Mixture

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Abstract. This paper assesses the heat transfer performance of nanofluids containing low concentration of core-shell structure of $SiO_2@TiO_2$ nanoparticles in a mixture of water and ethylene glycol (EG) in a commercially available heat exchanger. $SiO_2@TiO_2$ core-shell nanoparticles were prepared using modified Stöber method and characterized by using SEM, XRD, FTIR. Thermal properties of $SiO_2@TiO_2$ nanofluids, *i.e.* thermal conductivity, was determined by using transient hot wire experiments. For heat transfer analyses, 0 – 0.025% of $SiO_2@TiO_2$ nanofluids was employed in a finned-tube cross flow heat exchanger (automobile radiator kit). The results indicate that $SiO_2@TiO_2$ has an amorphous structure and is able to increase thermal conductivity as the fraction increases up to 0.04%. The thermofluid characteristics of nanofluid (Re, Nu, and Pr) increases leading to an increasing the convection coefficient. As the thermal conductivity and the convection coefficient increases, the total heat transfer coefficient improves. Finally, the heat transfer effectiveness increases linearly by 21% (from 0.203 to 0.246) upon using 0.025% mass fraction of $SiO_2@TiO_2$ to water/EG base fluid.

Key words Nanofluid, $SiO_2@TiO_2$ core shell, water – ethylene glycol mixture, automobile radiator, heat transfer

NOMENCLATURE			
φ	Mass fraction $SiO_2@TiO_2$ to water/EG	T_h	Temperature of hot nanofluids
V	Flow rate (m/s)	T_c	Temperature of cold nanofluids
D_h	Hydraulic diamater (m)	**Greek Symbols**	
Nu	Nusselt number	ρ	Density (kg/m^3)
Re	Reynold number	μ	Dynamic viscosity (Ns/m^2)
Pr	Prandtl number	**Subscripts**	
k	Conduction coefficient	nf	Nanofluid
h	Convection coefficient	bf	Base fluid
Q	Heat	in	inlet
U	Overall heat transfer coefficient	out	outlet
ε	Effectiveness		
ΔT_{LMTD}	Log mean temperature different		

1. INTRODUCTION

Operational of heat exchanger in industry is often facing less optimal thermal properties of the working fluid used, such as water, ethylene glycol, or oil, leading to the lower heat transfer effectiveness [1,2]. Increasing the overall heat exchanger performance can be achieved by improving the thermal properties of working fluids, one of which is by adding micrometer or nanometer-sized particles into the working fluid [3,4]. However, blockages in the heat transfer process can occur in heat exchanger tubes when using working fluids with large particles and high particle concentrations [5,6]. Therefore, the use of nanoparticles dispersed in the base fluid (nanofluid) is considered an alternative solution that not only increases the thermal conductivity of the working fluid but also increases the long-term stability and mantains a low pressure drop [7]. The utilization of nanofluids enable the enhancement of heat transfer effectiveness in laminar flow as increasing concentration of nanofluids also increase the Reynolds number [3-7]. This suggests an increasing the nanofluid convection coefficient.

Recent studies have been carried out to investigate the improved heat transfer mechanism in nanofluids bearing various metal oxide semiconductor nanomaterial, for example, TiO_2, Al_2O_3, CuO, and SiO_2 [3-12]. Amongst these nanomaterial, TiO_2 is one of the widely explored nanomaterials for the purpose of increasing heat transfer effectiveness due to its excellent chemical and thermophysical stability [6-11]. TiO_2 nanoparticles dispersed in various base fluids are widely used in various forms of heat exchangers. In addition, TiO_2 nanoparticles are cost-effective and commercially available. Increasing the concentration of TiO_2 is followed by an increase in the value of

Nusselt numbers and without an increase in pressure drop to a concentration of 0.25% [12]. Beside the n-type semiconductor TiO_2, other metal oxide such as SiO_2 which is more electrically insulator in an oil emulsion based nanofluids also exhibits promising heat transfer effectiveness[13-19]. It is found that increasing the concentration of SiO_2 nanofluid leads to the enhanced thermal conductivity without much changing its viscosity [14]. With concentration of only 0.5-3% SiO_2, it is already found to increase the heat transfer effectiveness by 43.75%.

In this study, we propose the utilization of SiO_2 and TiO_2 nanoparticles in the form of SiO_2@TiO_2 core-shell structure for nanofluids. Particularly, we evaluate the effect of low concentration of SiO_2@TiO_2 nanoparticles in water/ethylene glycol based nanofluid to the heat transfer effectiveness in cross-flow heat exchanger bearing finned tubes.

2. EXPERIMENTALS

2. 1. Synthesis of SiO_2@TiO_2 Core Shell Particle

Spherical SiO_2 particles were prepared using slightly modified Stöber method in a batch processed sol-precipitation. An amount of 2.725 mL TEOS were added drop wise under stirring at room temperature into a mixture of 180 mL ethanol, 30 mL saturated ammonia solution and 9 mL MilliQ water. The addition of TEOS was repeated four times every 12 h. After additional stirring for 6 h, 200 µL APTMS were added. The reaction solution was heated to reflux and kept stirring for 4 h. The particles where extracted from the reaction solution by centrifugation (3000 rpm, 6 min) and re-dispersed in 25 mL ethanol by ultrasonication for 30 min. 100 mg of SiO_2 nanoparticles were dispersed in 100 mL ethanol by ultrasonication for 30 min. The nanoparticle solution was heated to reflux and a solution of 200 µL TTIP in 20 mL ethanol was added under stirring to the reaction solution with a dropping funnel. The mixture was kept under reflux for 2.5 h. The particles where extracted from the reaction solution by centrifugation (3000 rpm, 6 min) and re-dispersed in 25 mL water by ultrasonication for 30 min.

2. 2. Characterization of SiO_2@TiO_2 Core Shell Particle

The micromorphology of SiO_2@TiO_2 core-shell particles was analyzed by Scanning Electron Microscopy (SEM) FEI Inspect-S50 operating at 20.0 kV accelerating voltage. The crystal structure of nanoparticles was determined by powder X-ray diffraction (XRD) with PANalytical X-pert MPD. The diffractometer was operated at 40kV and 20mA using a Cu-Kα radiation (λ = 0.15406 nm). The thermal conductivity of the nanofluids was assessed by using the transient hot wire technique.

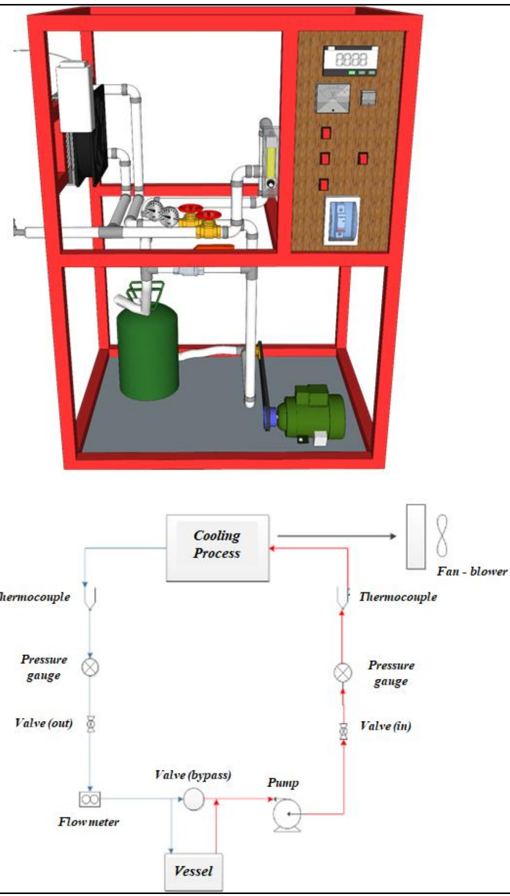

Figure 1. (*top*) The heat exchanger apparatus and (*bottom)* the schematic its component.

2.3. Heat Transfer Apparatus and Analysis

The effectiveness of heat transfer was assessed in the experimental heat transfer system, *i.e.*, automobile radiator training kit, including a closed loop of hot and cold flow (Fig. 1). The heat exchanger was finned-tube cross flow heat exchanger (Suzuki). The $SiO_2@TiO_2$ in a mixture of EG:water (1:1 v/v) nanofluid was employed as the hot fluid in the system. The concentration was varied in the range of 0 – 0.025% mass fraction of $SiO_2@TiO_2$ to EG:water base fluids. The system was functionalized with the calibrated thermocouples, flow meter and pressure gauges. The schematic diagram of the automobile radiator training kit is shown in Fig. 1.

Performance of heat exchanger using different concentration of $SiO_2@TiO_2$ was evaluated by the heat tranfer effectiveness. Heat transfer parameters of nanofluids were determined by joint experimental and theoretical approach, *i.e.* only conductivity is directly determined from transient hot wire measurements. The other parameters are determined as follows [1,2,17-22]:

- Density of nanofluids

$\rho_{nf} = (1-\varphi)\rho_{bf} + \varphi\rho_{bf}$	(1)

- Viscosity of nanofluids (Einstein equation)

$\mu_{nf} = (1+2,5\varphi)\mu_{bf}$	(2)

- Reynold number (Re)

$\mathrm{Re} = \dfrac{\rho \times V \times D_h}{\mu}$	(3)

- Nusselt number (*Nu*) of external flow

$$Nu = 0,683 \times \mathrm{Re}^{0,38} \times \mathrm{Pr}^{0,37} \times \left(\frac{\mathrm{Pr}}{\mathrm{Pr}_s} \right)^{0,25} \qquad (4)$$

- Nusselt number (Nu) of internal flow

$$Nu = 0,0265 \times \mathrm{Re}^{0,8}\,\mathrm{Pr}^{0,36} \qquad (5)$$

- Convection coefficient (h_{nf}) of nanofluids

$$h_{nf} = 0,295 \left(\frac{k_w}{D_h} \right) \mathrm{Re}^{0,64}\,\mathrm{Pr}^{0,32} \left(\frac{\pi}{2} \right) \qquad (6)$$

- Convection coefficient (h) of air

$$h = \frac{Nu \times k_f}{D_h} \qquad (7)$$

Once all above parameters were determined, the overal heat transfer coefficient (U) was estimated. For a single tube heat exchanger, U was determined as follows:

$$U = \frac{1}{\frac{1}{h_i} + \frac{\Delta x}{k_w} + \frac{1}{h_o}} \qquad (8)$$

Finally, the heat transfer rate which involves convection and conduction was evaluated by the following:

$$Q = U \times \mathrm{A} \times \Delta \mathrm{T}_{LMTD} \qquad (9)$$

$$\Delta \mathrm{T}_{LMTD} = \frac{(T_{h,in} - T_{c,out}) - (T_{h,out} - T_{c,in})}{\ln \left[\frac{(T_{h,in} - T_{c,out})}{(T_{h,out} - T_{c,in})} \right]} \qquad (10)$$

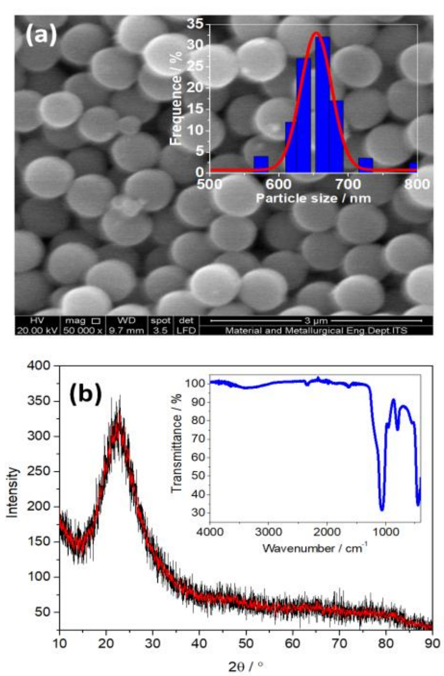

Figure 2. (a) Scanning electron micrograph and (b) XRD pattern of $SiO_2@TiO_2$. Inset of (b) indicates FTIR spectra of

$SiO_2@TiO_2$.

3. RESULTS AND DISCUSSION

3.1. Physical Properties of $SiO_2@TiO_2$ Core Shell Particle

The morphology of $SiO_2@TiO_2$ core-shell particles is displayed in Fig. 2a. The average size of $SiO_2@TiO_2$ is 640 nm and the particle size distribution indicates that the resulting $SiO_2@TiO_2$ particles is considered monodisperse. To understand the underlying structure of $SiO_2@TiO_2$ core-shell particles XRD patterns of the $SiO_2@TiO_2$ core-shell and TiO_2 after calcination at 500◦C for 3 h are recored (Fig. 2b). All the SiO_2/TiO_2 core-shell particles started to show clear anatase peaks corresponding to the planes (1 0 1), (0 0 4), and (200) at 2θ = 25.3, 37.8, and 48.1, respectively. With increasing the number of coating steps, the FWHM (full width at half max-imum) of anatase peaks decreased indicating larger crystallite sizes. Nonetheless, higher X-ray diffraction background indicates that the nanoparticle is amorphous. Inset of Fig. 2b shows FT-IR patterns of $SiO_2@TiO_2$ core-shell particles. The absorption band at 460 cm^{-1} is assigned for Si-O-Si bending modes which appears in the same range of Ti-O-Ti band (400–600 cm^{-1}) for $SiO_2@TiO_2$ core-shell particles. The absorption peak at 940 cm^{-1} is observed in the spectrum of $SiO_2@TiO_2$ core-shell particles indicating the characteristic vibration of Ti-O-Si.

3.2. Thermal Properties of $SiO_2@TiO_2$ Nanofluids

To aid the heat transfer analysis, the thermal conductivity of the prepared $SiO_2@TiO_2$ core-shell nanofluids is assessed by transient hot-wire measurements and summarized in Fig. 3. The thermal conductivity of water-EG mixture is 13.2 $W \cdot m^{-2} \cdot K^{-1}$ and increases by 19.7% with inclining mass fraction of $SiO_2@TiO_2$ core-shell nanoparticle up to 0.04%. However, the thermal conductivity further decreases upon higher fraction of $SiO_2@TiO_2$ core-shell nanoparticle.

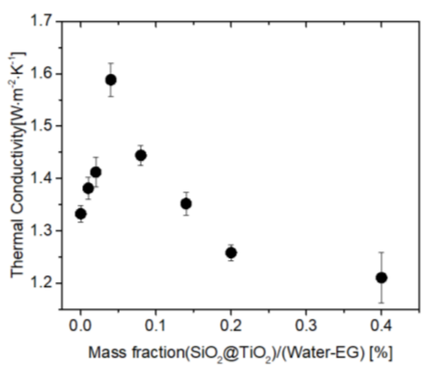

Figure 3. Thermal conductivity of $SiO_2@TiO_2$ nanofluids determined from transient hot wire measurements.

The increasing and decreasing thermal conductivtiy in $SiO_2@TiO_2$ nanofluid can be described as follows: The nanoparticles, which has large surface area for energy exchange, acts as energy absorber and storage which are transported by diffusion or forced convection (flow). Therefore, a maximum thermal transport will be achieved when sufficient amount of $SiO_2@TiO_2$ particles, whose thermal conductivity and heat capacity is higher than the base fluid, is reached. Nonetheless, the there is saturated concentration of nanoparticles in nanofluid which behaves like turning point (global maximum), in which higher concentration of nanoparticles will result in the worse particle diffusion and possible agglomeration/aggregation and hence, reduces the overal thermal conductance of the nanoparticle/fluid system.

3.3. Heat Transfer Analysis

The heat transfer performance of $SiO_2@TiO_2$ nanofluids can be indirectly assessed by dynamic of temperature changes in the hot (T_h) and cold (T_c) stream upon varying the nanofluid concentration, *i.e.* mass fraction of $SiO_2@TiO_2$ to water/ethylene glycol, from 0 – 0.025% as shown in Fig. 4. The results show that outflow of T_h and T_c is decreasing and increasing, respectively, with increasing concentration of $SiO_2@TiO_2$ nanofluids. This further indicates that the higher the concentration of nanofluids, the higher the heat is transferred. In addition, this seemingly increasing heat transfer upon increasing nanofluid concentration up to 0025% is in a good agreement with the thermal properties of investigated nanofluids as discussed earlier. It should be noted that the thermal conductivity of SiO_2@TiO_2 increases up to 0.040% mass fraction.

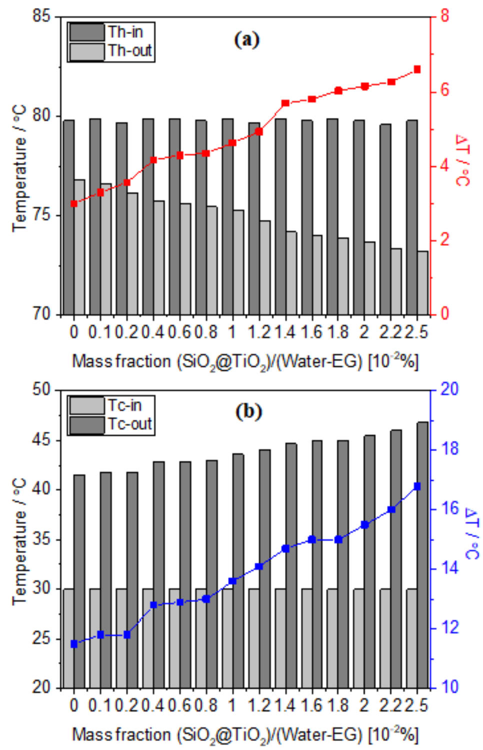

Figure 4. Inlet and outlet temperature of (a) hot and (b) cold stream of nanofluids in heat exchanger apparatus.

The SiO_2@TiO_2 nanoparticles also affects the density of nanofluid determining the Reynold number (Re). Higher Re implies a dominant inertial force which speeds up the movement of molecules accelerating the rate of heat transfer. In addition, thermal conductivity depends on the mass fraction of the nanofluid, the size and morphology of the particles, and the base fluid characteristics. The addition of SiO_2@TiO_2 nanoparticles results in an increase in the work surface of the heat transfer area. Nonetheless, agglomeration of nanoparticles should be avoided in practical application [20-22], since this can change the thermal characteristics of the nanoparticles themselves, which affects the heat transfer process.

The external forced convection in this study is supported by blowers with an average speed of 6.8 m□s^{-1} and a temperature of 30°C. Addition of SiO_2@TiO_2 mass fraction to the base fluid can result in an increase in the value of the convection coefficient of nanofluid (Fig. 5). Furthermore, the change in fraction affects the convection coefficient of the air since there is a change in temperature indicating an increasing contact surface area during the heat transfer process. The addition of SiO_2@TiO_2 nanoparticles at a concentration of 0.025% can increase the heat transfer coefficient by up to 9.15%. The convection coefficient increases with increasing mass fraction of nanoparticles is also reported by other study [6]. The earlier study indicates that the convection coefficient is improvey by 6.6% at a TiO_2 mass fraction of 0.3%.

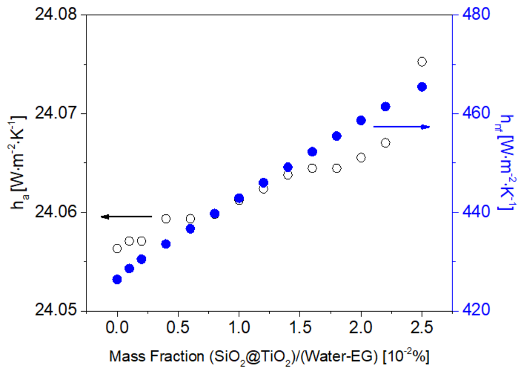

Figure 5. The estimated convection coefficient of air (h_a) and $SiO_2@TiO_2$ nanofluids (h_{nf}).

Referring to the calculation of thermal conductivity and convection coefficient in the earlier discussion, the total heat transfer coefficient value is evaluated and the results are described as follows: The total heat transfer coefficient does not significantly increase, that is ca. 0.03-0.07% for each increment of mass fraction. This results is also in line with other study [8], that the total heat transfer coefficients in the fractions of 0.3%, 0.8%, and 1.5% (at a certain Re) only slightly increases. The overall heat transfer evaluation is based on the Newton equation. As the heat exchanger used in this study using cross-flow configuration, the log man temperature difference (ΔT_{LMTD}) is used to calculate the heat transfer rate (Fig. 6).

At the same flow rate, *i.e.* 8 litre per min (LPM), increasing the concentration of $SiO_2@TiO_2$ nanoparticles up to 0.025% results in an increase of heat transfer rate up to 18.11% (from 2168 W□m^{-2} to 2344 W□m^{-2}). This result is found higher than the heat transfer rate of water based nanofluid containing TiO_2 nanoparticles: At a concentration of 0.25%, the heat transfer rate is only enhanced by 11% [22]. Other study reported that at the flowrate of 1.8 LPM the TiO^2-based nanofluids are able to produce a heat transfer rate of around 5000 W□m^{-2} and increased to 8000 W□m^{-2} when the flowrate is doubled. This implies that the heat transfer rate of the investigated low concentration $SiO_2@TiO_2$ nanofluids can be improved by increasing the flowrate of nanofluids in the heat exchanger.

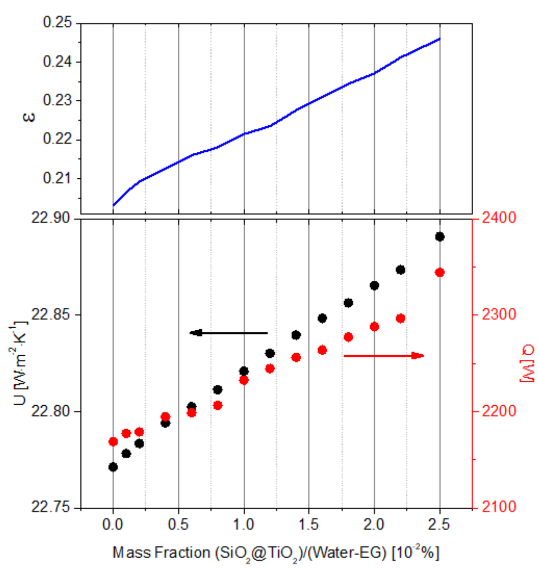

Figure 6. The overal heat transfer coefficient (U), heat rate (W), and heat transfer effectiveness (ε) in heat exchanger using different concentration of $SiO_2@TiO_2$ nanofluids.

In general, according to the energy conservation law, the effectiveness of heat transfer using different $SiO_2@TiO_2$ concentration is linearly enhanced when the mass fraction of nanoparticles to base fluid is increased [Fig. 6]. It is shown that the effectiveness of heat transfer increases by 1.6 - 2% for increasisng mass fraction by 0.005%. Overall, there is an increase in the effectiveness of heat transfer by 21%, *i.e.* from 0.203 to 0.246, when the concentration of 0% is added to 0.025%. The results at hand indicate that the investigated system, *i.e.* EG:water based nanofluid containing $SiO_2@TiO_2$ nanopartices, is better than other study using EG:water (3:2) based nanofluid containing 0.02% TiO_2 which is only able to increase the effectiveness of heat transfer by 13% [19].

4. CONCLUSIONS

It has been successfully prepared and evaluated EG:water based nanofluids containing $SiO_2@TiO_2$ core-shell nanoparticles for application of finned tube cross-flow heat exchanger. Increasing mass fraction of $SiO_2@TiO_2$ nanoparticles to EG:water base fluid can improve the thermophysical characteristics and thermal characteristics of nanofluid. The saturation concentration of $SiO_2@TiO_2$ nanoparticles in nanofluid is 0.04%. From the mass fraction of 0% to 0.025%, the total heat transfer coefficient increases from 22.77 $W \cdot m^{-2} \cdot K^{-1}$ to 22.89 $W \cdot m^{-2} \cdot K^{-1}$ resulting in the enhancing heat transfer rate in the exchanger from 2168 $W \cdot m^{-2}$ to 2344 $W \cdot m^{-2}$. Furthermore, the effectiveness of heat transfer also increases from 0.203 to 0.246.

5. ACKNOWLEDGMENT

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RE: Manuscript Submission (163-2019)

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Dear Dr. I Made Arsana,

This is to confirm the receipt of your paper "Enhanced Heat Transfer Effectiveness Using Low Concentration SiO_2@TiO_2 Core-Shell Nanofluid in Water/Ethylene Glycol Mixture" (reg. number 163-2019). The paper will be sent to the referees for their comments. We'll communicate with you as we have the referees' comments.

With best wishes,

Managing Editor

Larissa Shemet

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Dear Managing Editor
Larissa Shemet

We really appreciate your fast response. Look forward to hearing the good news from you.
Thank you

Best regards,
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Dear Dr. Arsana,

We, Editors of the Journal of Engineering Physics and Thermophysics, considered your (in coauthorship) paper "Enhanced Heat Transfer Effectiveness Using Low Concentration SiO_2@TiO_2 Core-Shell Nanofluid in Water/Ethylene Glycol Mixture" (No. 163-2019) and concluded that it can be published in the Journal. However, we would like to inform you that:

1) the Journal of Engineering Physics and Thermophysics is a translation of Inzhenerno-Fizicheskii Zhurnal (a publication of the Academy of Sciences of Belarus). Most of the papers published in the Zhurnal are sent to the Editorial Board in Russian, and only two–three papers submitted in English are published in each issue. We have a very long queue of submitted papers in English, so that your paper cannot be published in the nearest future;

2) the paper should be prepared according to the attached Rules of the Journal;

3) in the paper, dimensionality of the thermal conductivity is presented incorrectly: it should be $W \; m^{-1} \; K^{-1}$.

Best regards,

Editors

From: I Made Arsana [mailto:madearsana@unesa.ac.id]
Sent: Tuesday, July 30, 2019 5:29 PM
To: jepter@itmo.by
Subject: Manuscript Submission

July 30, 2019

I Made Arsana <madearsana@unesa.ac.id>

Manuscript Submission

I Made Arsana <madearsana@unesa.ac.id> 9 September 2019 20.30
Kepada: jepter@itmo.by

Dear Editor,

Thank you for the information, we are glad that our paper is accepted in Journal of Engineering Physics and Thermophysics,
By this email we would like to confirm:
1. The revised paper is attached, after considering the rules and the correction related to writing of dimensionality of the thermal conductivity
2. About the publishing, could we know how long does it take for the queue? And could we get the Letter of Acceptance (LoA), while waiting for the publication ?

Best regards,
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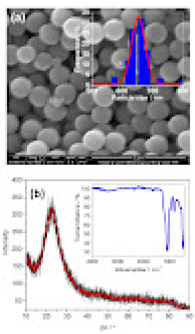

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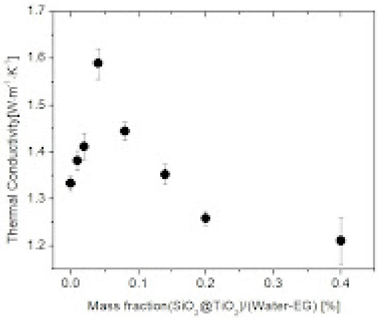

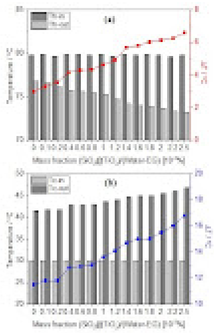

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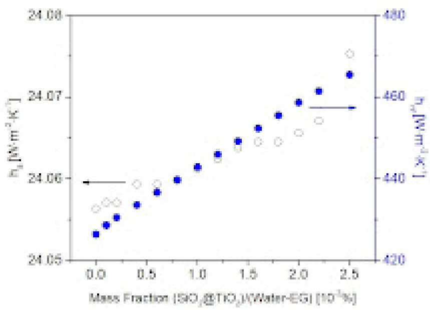

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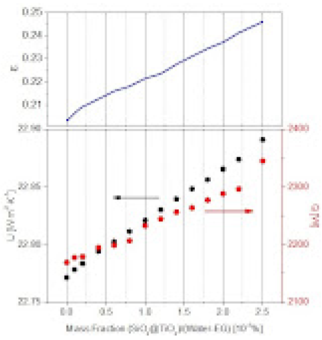

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[UDC 536+544]

I. M. Arsana[a], L. C. Muhimmah[b], G. Nugroho[b], R. A. Wahyuono[b]

ENHANCED HEAT TRANSFER EFFECTIVENESS USING LOW CONCENTRATION $SiO_2@TiO_2$ CORE-SHELL NANOFLUID IN WATER/ETHYLENE GLYCOL MIXTURE

Abstract. This paper assesses the heat transfer performance of nanofluids containing low concentration of core-shell structure of $SiO_2@TiO_2$ nanoparticles in a mixture of water and ethylene glycol (EG) in a commercially available heat exchanger. For heat transfer analyses, 0 – 0.025% of $SiO_2@TiO_2$ nanofluids was employed in a finned-tube cross flow heat exchanger (automobile radiator kit). The results indicate that $SiO_2@TiO_2$ has an amorphous structure and enable increasing thermal conductivity as the fraction increases up to 0.04%. The thermofluid characteristics of nanofluid (Re, Nu, and Pr) increases leading to an increasing the convection coefficient. As the thermal conductivity and the convection coefficient increases, the total heat transfer coefficient improves. Finally, the heat transfer effectiveness increases linearly by 21% upon using 0.025% mass fraction of $SiO_2@TiO_2$ to water/EG base fluid.

Keywords: **Nanofluid, *$SiO_2@TiO_2$, EG/water mixture, Automobile radiator, Heat transfer.***

Introduction. Operational of heat exchanger in industry is often facing less optimal thermal properties of the working fluid used, such as water, ethylene glycol, or oil, leading to the lower heat transfer effectiveness [1,2]. Increasing the overall heat exchanger performance can be achieved by improving the thermal properties of working fluids, one of which is by adding micrometer or nanometer-sized particles into the working fluid [3,4]. However, blockages in the heat transfer process can occur in heat exchanger tubes when using working fluids with large particles and high particle concentrations [5,6]. Therefore, the use of nanoparticles dispersed in the base fluid (nanofluid) is considered an alternative solution that not only increases the thermal conductivity of the working fluid but also increases the long-term stability and mantains a low pressure drop [7]. The utilization of nanofluids enable the enhancement of heat transfer effectiveness in laminar flow as increasing concentration of nanofluids also increase the Reynolds number [3-7]. This suggests an increasing the nanofluid convection coefficient.

Recent studies have been carried out to investigate the improved heat transfer mechanism in nanofluids bearing various metal oxide semiconductor nanomaterial, for example, TiO_2, Al_2O_3, CuO, and SiO_2 [3-12]. Amongst these nanomaterials, TiO_2 is one of the widely explored nanomaterials for the purpose of increasing heat transfer effectiveness due to its excellent chemical and thermophysical stability [6-11]. TiO_2 nanoparticles dispersed in various base fluids are widely used in various forms of heat exchangers. In addition, TiO_2 nanoparticles are cost-effective and commercially available. Increasing the concentration of TiO_2 is followed by an increase in the value of Nusselt numbers and without an increase in pressure drop to a concentration of 0.25% [12]. Beside the n-type semiconductor TiO_2, other metal oxide such as SiO_2 which is more electrically insulator in an oil emulsion based nanofluids also exhibits promising heat transfer effectiveness [13-19]. It is found that increasing the concentration of SiO_2 nanofluid leads to the enhanced thermal conductivity without much changing its viscosity [14]. With concentration of only 0.5-3% SiO_2, it is already found to increase the heat transfer effectiveness by 43.75%.

In this study, we propose the utilization of SiO_2 and TiO_2 nanoparticles in the form of SiO_2@TiO_2 core-shell structure for nanofluids. Particularly, we evaluate the effect of low concentration of SiO_2@TiO_2 nanoparticles in water/ethylene glycol based nanofluid to the heat transfer effectiveness in cross-flow heat exchanger bearing finned tubes.

Materials and Method. Spherical SiO_2 particles were prepared using slightly modified Stöber method in a batch processed sol-precipitation. An amount of 2.725 mL TEOS were added drop wise under stirring at room temperature into a mixture of 180 mL ethanol, 30 mL saturated ammonia solution and 9 mL MilliQ water. The addition of TEOS was repeated four times every 12 h. After additional stirring for 6 h, 200 µL APTMS were added. The reaction solution was heated to reflux and kept stirring for 4 h. The particles where extracted from the reaction solution by centrifugation (3000 rpm, 6 min) and re-dispersed in 25 mL ethanol by ultrasonication for 30 min. 100 mg of SiO_2 nanoparticles were dispersed in 100 mL ethanol by ultrasonication for 30 min. The nanoparticle solution was heated to reflux and a solution of 200 µL TTIP in 20 mL ethanol was added under stirring to the reaction solution with a dropping funnel. The mixture was kept under reflux for 2.5 h. The particles where extracted from the reaction solution by centrifugation (3000 rpm, 6 min) and re-dispersed in 25 mL water by ultrasonication for 30 min. The micromorphology of SiO_2@TiO_2 core-shell particles was analyzed by Scanning Electron Microscopy (SEM) FEI Inspect-S50 operating at 20.0 kV accelerating voltage. The crystal structure of nanoparticles was determined by powder X-ray diffraction (XRD) with PANalytical X-pert MPD. The diffractometer was operated at 40kV and 20mA using a Cu-Kα radiation (λ = 0.15406 nm). The thermal conductivity of the nanofluids was assessed by using the transient hot wire technique.

The effectiveness of heat transfer was assessed in the experimental heat transfer system, *i.e.*, automobile radiator training kit, including a closed loop of hot and cold flow (Fig. 1). The heat exchanger was finned-tube cross flow heat exchanger (Suzuki). The $SiO_2@TiO_2$ in a mixture of EG:water (1:1 v/v) nanofluid was employed as the hot fluid in the system. The concentration was varied in the range of 0 – 0.025% mass fraction of $SiO_2@TiO_2$ to EG:water base fluids. The system was functionalized with the calibrated thermocouples, flow meter and pressure gauges. The schematic diagram of the automobile radiator training kit is shown in Fig. 1. Performance of heat exchanger using different concentration of $SiO_2@TiO_2$ was evaluated by the heat tranfer effectiveness. Heat transfer parameters of nanofluids were determined by joint experimental and theoretical approach, *i.e.* only conductivity is directly determined from transient hot wire measurements. The other parameters are determined as follows [1,2,17-19]:

- Density of nanofluids

$$\rho_{nf} = (1-\varphi)\rho_{bf} + \varphi\rho_{bf} \quad (1)$$

- Viscosity of nanofluids (Einstein equation)

$$\mu_{nf} = (1+2,5\varphi)\mu_{bf} \quad (2)$$

- Reynold number (Re)

$$\mathrm{Re} = \frac{\rho \times V \times D_h}{\mu} \quad (3)$$

- Nusselt number (*Nu*) of external flow

$$Nu = 0,683 \times \mathrm{Re}^{0,38} \times \mathrm{Pr}^{0,37} \times \left(\frac{\mathrm{Pr}}{\mathrm{Pr}_s}\right)^{0,25} \quad (4)$$

- Nusselt number (*Nu*) of internal flow

$$Nu = 0,0265 \times \mathrm{Re}^{0,8}\,\mathrm{Pr}^{0,36} \quad (5)$$

- Convection coefficient (h_{nf}) of nanofluids

$$h_{nf} = 0,295\left(\frac{k_w}{D_h}\right)\mathrm{Re}^{0,64}\,\mathrm{Pr}^{0,32}\left(\frac{\pi}{2}\right) \quad (6)$$

- Convection coefficient (h) of air

$$h = \frac{Nu \times k_f}{D_h} \tag{7}$$

Once all above parameters were determined, the overal heat transfer coefficient (U) was estimated. For a single tube heat exchanger, U was determined as follows:

$$U = \frac{1}{\frac{1}{h_i} + \frac{\Delta x}{k_w} + \frac{1}{h_o}} \tag{8}$$

Finally, the heat transfer rate which involves convection and conduction was evaluated by the following:

$$Q = U \times \mathrm{A} \times \Delta \mathrm{T}_{LMTD} \tag{9}$$

where

$$\Delta \mathrm{T}_{LMTD} = \frac{(T_{h,in} - T_{c,out}) - (T_{h,out} - T_{c,in})}{\ln\left[\frac{(T_{h,in} - T_{c,out})}{(T_{h,out} - T_{c,in})}\right]} \tag{10}$$

Physical Properties of SiO_2@TiO_2 Core Shell Particle. The morphology of SiO_2@TiO_2 core-shell particles is displayed in Fig. 2a. The average size of SiO_2@TiO_2 is 640 nm and the particle size distribution indicate that the resulting SiO_2@TiO_2 particles is considered monodisperse. To understand the underlying structure of SiO_2@TiO_2 core-shell particles XRD patterns of the SiO_2@TiO_2 core-shell and TiO_2 after calcination at 500◦C for 3 h are recored (Fig. 2b). All the SiO_2/TiO_2 core-shell particles started to show clear anatase peaks corresponding to the planes (1 0 1), (0 0 4), and (200) at 2θ = 25.3, 37.8, and 48.1, respectively. With increasing the number of coating steps, the FWHM (full width at half maximum) of anatase peaks decreased indicating larger crystallite sizes. Nonetheless, higher X-ray diffraction background indicates that the nanoparticle is amorphous. Inset of Fig. 2b shows FT-IR patterns of SiO_2@TiO_2 core-shell particles. The absorption band at 460 cm^{-1} is assigned for Si-O-Si bending modes which appears in the same range of Ti-O-Ti band (400–600 cm^{-1}) for SiO_2@TiO_2 core-shell particles [20,21]. The absorption peak at 940 cm^{-1} is observed in the spectrum of SiO_2@TiO_2 core-shell particles indicating the characteristic vibration of Ti-O-Si.

Thermal Properties of SiO_2@TiO_2 Nanofluids. To aid the heat transfer analysis, the thermal conductivity of the prepared $SiO_2@TiO_2$ core-shell nanofluids is assessed by transient hot-wire measurements and summarized in Fig. 3. The thermal conductivity of water-EG mixture is 13.2 $W·m^{-1}·K^{-1}$ and increases by 19.7% with inclining mass fraction of $SiO_2@TiO_2$ core-shell nanoparticle up to 0.04%. However, the thermal conductivity further decreases upon higher fraction of $SiO_2@TiO_2$ core-shell nanoparticle. The increasing and decreasing thermal conductivtiy in $SiO_2@TiO_2$ nanofluid can be described as follows: The nanoparticles, which has large surface area for energy exchange, acts as energy absorber and storage which are transported by diffusion or forced convection (flow). Therefore, a maximum thermal transport will be achieved when sufficient amount of $SiO_2@TiO_2$ particles, whose thermal conductivity and heat capacity is higher than the base fluid, is reached. Nonetheless, the there is saturated concentration of nanoparticles in nanofluid which behaves like turning point (global maximum), in which higher concentration of nanoparticles will result in the worse particle diffusion and possible agglomeration/aggregation and hence, reduces the overal thermal conductance of the nanoparticle/fluid system.

Heat Transfer Analysis. The heat transfer performance of $SiO_2@TiO_2$ nanofluids can be indirectly assessed by dynamic of temperature changes in the hot (T_h) and cold (T_c) stream upon varying the nanofluid concentration, *i.e.* mass fraction of $SiO_2@TiO_2$ to water/ethylene glycol, from 0 – 0.025% as shown in Fig. 4. The results show that outflow of T_h and T_c is decreasing and increasing, respectively, with increasing concentration of $SiO_2@TiO_2$ nanofluids. This further indicates that the higher the concentration of nanofluids, the higher the heat is transferred. In addition, this seemingly increasing heat transfer upon increasing nanofluid concentration up to 0025% is in a good agreement with the thermal properties of investigated nanofluids as discussed earlier. It should be noted that the thermal conductivity of $SiO_2@TiO_2$ increases up to 0.040% mass fraction.

The $SiO_2@TiO_2$ nanoparticles also affects the density of nanofluid determining the Reynold number (Re). Higher Re implies a dominant inertial force which speeds up the movement of molecules accelerating the rate of heat transfer. In addition, thermal conductivity depends on the mass fraction of the nanofluid, the size and morphology of the particles, and the base fluid characteristics. The addition of $SiO_2@TiO_2$ nanoparticles results in an increase in the work surface of the heat transfer area. Nonetheless, agglomeration of nanoparticles should be avoided in practical application [23-25], since this can change the thermal characteristics of the nanoparticles themselves, which affects the heat transfer process.

The external forced convection in this study is supported by blowers with an average speed of 6.8 m□s^{-1} and a temperature of 30°C. Addition of $SiO_2@TiO_2$ mass fraction to the base fluid can result in an increase in the value of the convection coefficient of nanofluid (Fig. 5). Furthermore, the change in fraction affects the convection coefficient of the air since there is a change in temperature indicating an increasing contact surface area during the heat transfer process. The addition of $SiO_2@TiO_2$ nanoparticles at a concentration of 0.025% increase the heat transfer coefficient by 9.15%. The convection coefficient increases with increasing mass fraction of nanoparticles is also reported by other study [6]. The earlier study indicates that the convection coefficient is improved by 6.6% at a TiO_2 mass fraction of 0.3%.

Referring to the calculation of thermal conductivity and convection coefficient in the earlier discussion, the total heat transfer coefficient value is evaluated, and the results are described as follows: The total heat transfer coefficient does not significantly increase, that is ca. 0.03-0.07% for each increment of mass fraction. This result is also in line with other study [8], that the total heat transfer coefficients in the fractions of 0.3%, 0.8%, and 1.5% (at a certain Re) only slightly increases. The overall heat transfer evaluation is based on the Newton equation. As the heat exchanger used in this study using cross-flow configuration, the log man temperature difference (ΔT_{LMTD}) is used to calculate the heat transfer rate (Fig. 6).

At the same flow rate, *i.e.* 8 litre per min (LPM), increasing the concentration of $SiO_2@TiO_2$ nanoparticles up to 0.025% results in an increase of heat transfer rate up to 18.11% (from 2168 W□m^{-2} to 2344 W□m^{-2}). This result is found higher than the heat transfer rate of water based nanofluid containing TiO_2 nanoparticles: At a concentration of 0.25%, the heat transfer rate is only enhanced by 11% [25]. Other study reported that at the flowrate of 1.8 LPM the TiO^2-based nanofluids are able to produce a heat transfer rate of around 5000 W□m^{-2} and increased to 8000 W□m^{-2} when the flowrate is doubled. This implies that the heat transfer rate of the investigated low concentration $SiO_2@TiO_2$ nanofluids can be improved by increasing the flowrate of nanofluids in the heat exchanger.

In general, according to the energy conservation law, the effectiveness of heat transfer using different $SiO_2@TiO_2$ concentration is linearly enhanced when the mass fraction of nanoparticles to base fluid is increased (Fig. 6). It is shown that the effectiveness of heat transfer increases by 1.6 - 2% for increasisng mass fraction by 0.005%. Overall, there is an increase in the effectiveness of heat transfer by 21%, *i.e.* from 0.203 to 0.246, when the concentration of 0% is added to 0.025%. The results at hand indicate that the investigated system, *i.e.* EG:water based nanofluid containing $SiO_2@TiO_2$ nanopartices, is better than other study using EG:water (3:2) based nanofluid containing 0.02% TiO_2 which is only able to increase the effectiveness of heat transfer by 13% [19].

Conclusion. It has been successfully prepared and evaluated EG:water based nanofluids containing SiO_2@TiO_2 core-shell nanoparticles for application of finned tube cross-flow heat exchanger. Increasing mass fraction of SiO_2@TiO_2 nanoparticles to EG:water base fluid can improve the thermophysical characteristics and thermal characteristics of nanofluid. The saturation concentration of SiO_2@TiO_2 nanoparticles in nanofluid is 0.04%. From the mass fraction of 0% to 0.025%, the total heat transfer coefficient increases from 22.77 $W\cdot m^{-2}\cdot K^{-1}$ to 22.89 $W\cdot m^{-2}\cdot K^{-1}$ resulting in the enhancing heat transfer rate in the exchanger from 2168 $W\cdot m^{-2}$ to 2344 $W\cdot m^{-2}$. Furthermore, the effectiveness of heat transfer also increases from 0.203 to 0.246.

Notations. D_h, hydraulic diameter, m; h, convective heat transfer coefficient, $W\cdot m^{-2}\cdot K^{-1}$; k, conductive heat transfer coefficient, $W\cdot m^{-1}\cdot K^{-1}$; Nu, Nusselt number; Pr, Prandtl number; Q, heat rate, W; Re, Reynold number; U, overall heat transfer coefficient, $W\cdot m^{-2}\cdot K^{-1}$; T, temperature, K; V, flow rate, m/s; ΔT_{LMTD},log mean temperature different, K; ε, heat transfer effectiveness; φ, mass fraction SiO_2@TiO_2 to water/EG; Indices: h, hot nanofluids; c, cold nanofluids; nf, nanofluid; bf, base fluid; in, inlet; out, outlet.

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Figure Caption:

Figure 1. (*top*) The heat exchanger apparatus and (*bottom)* the schematic its component.

Figure 2. (a) Scanning electron micrograph and (b) XRD pattern of $SiO_2@TiO_2$. Inset of (b) indicates FTIR spectra of $SiO_2@TiO_2$

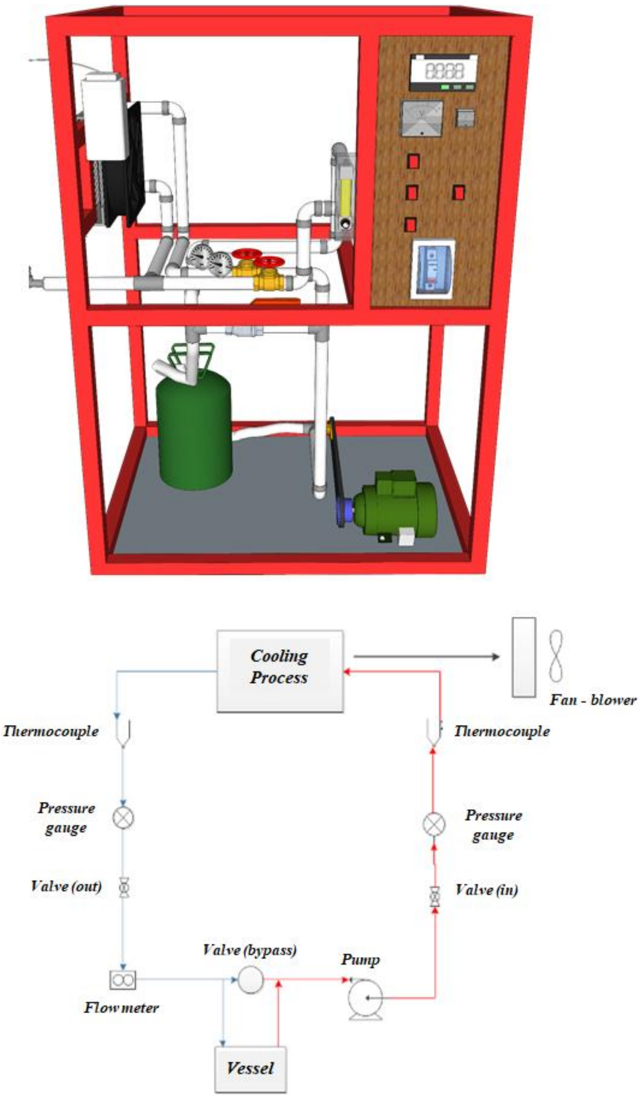
Figure 3. Thermal conductivity of $SiO_2@TiO_2$ nanofluids determined from transient hot wire measurements.

Figure 4. Inlet and outlet temperature of (a) hot and (b) cold stream of nanofluids in heat exchanger apparatus.

Figure 5. The estimated convection coefficient of air (h_a) and $SiO_2@TiO_2$ nanofluids (h_{nf}).

Figure 6. The overal heat transfer coefficient (U), heat rate (W), and heat transfer effectiveness (ε) in heat exchanger using different concentration of $SiO_2@TiO_2$ nanofluids.

Figures:



Cooling Process
Fan - blower
Thermocouple
Thermocouple
Pressure gauge
Pressure gauge
Valve (out)
Valve (in)
Valve (bypass)
Pump
Flow meter
Vessel

Figure 1.

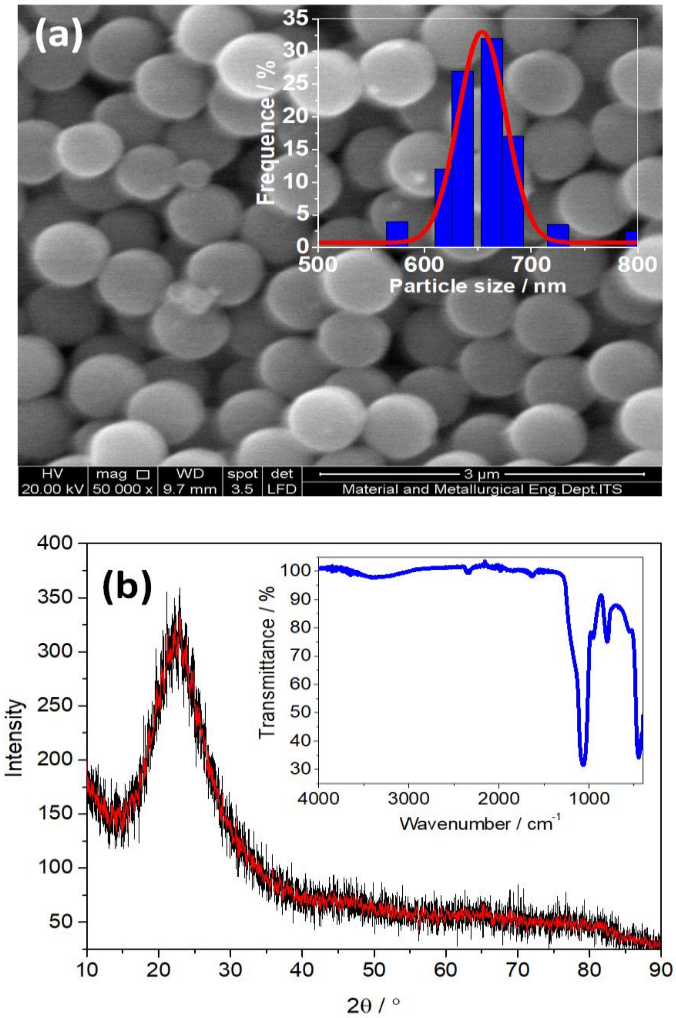


Figure 2.

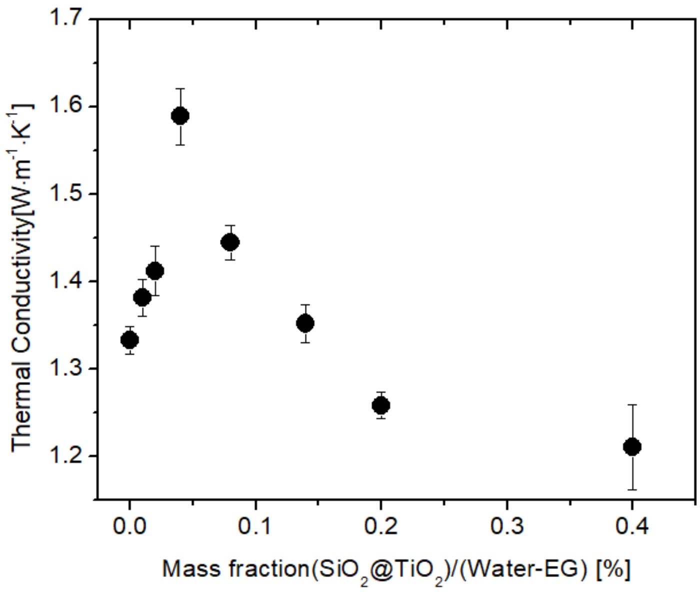


Figure 3.

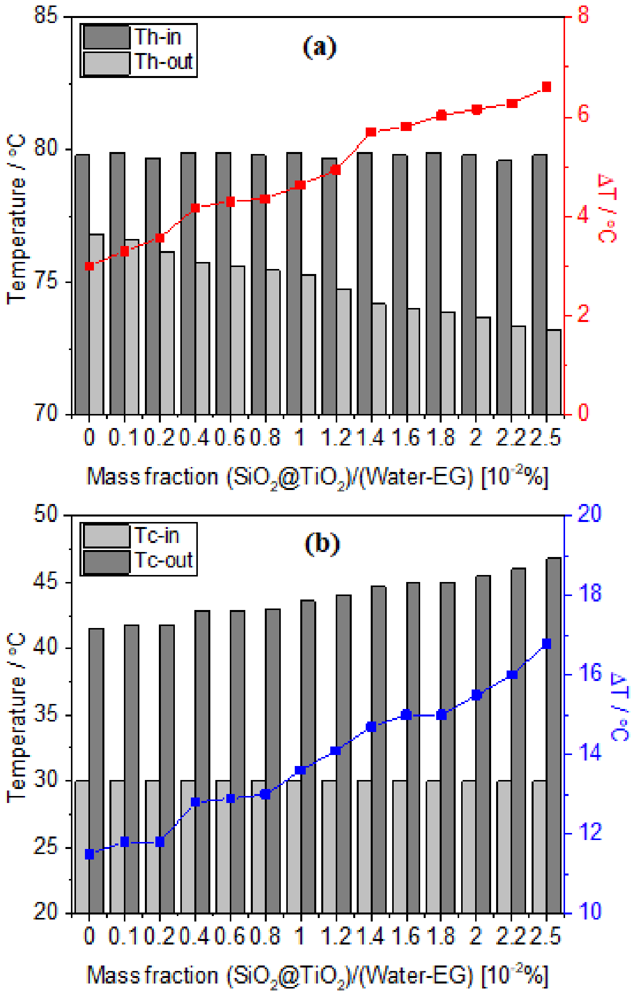


Figure 4.

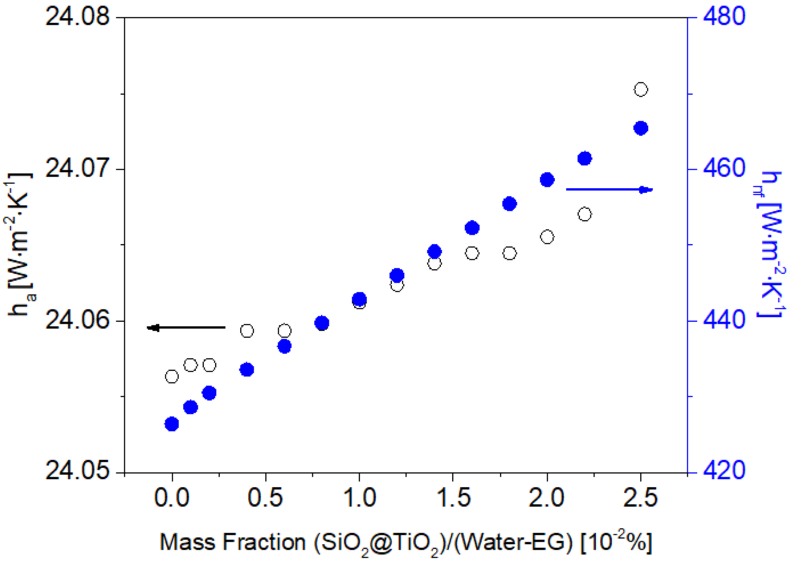


Figure 5.

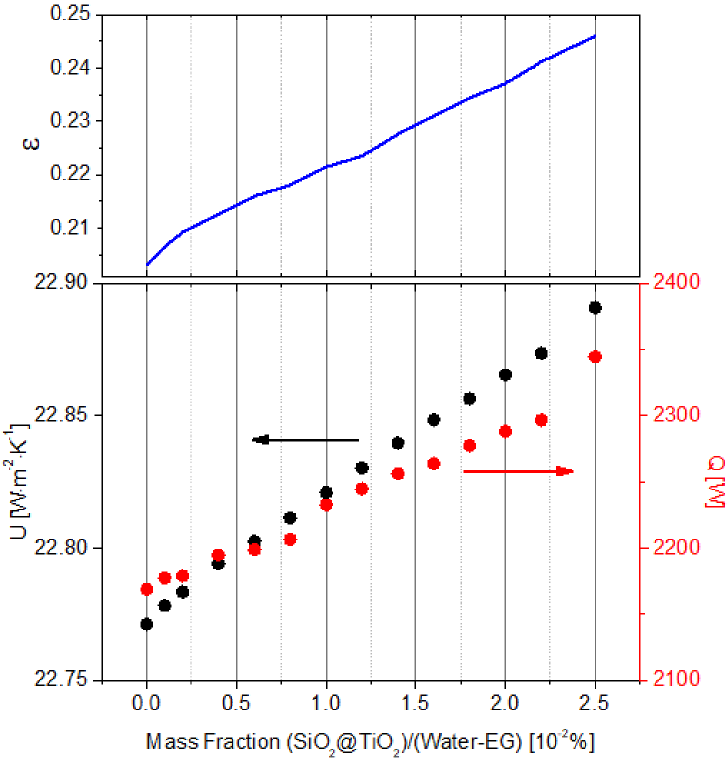


Figure 6.

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I Made Arsana <madearsana@unesa.ac.id>

RE: Manuscript Submission (163-2019)

Jepter <jepter@itmo.by> 12 September 2019 16.16
Balas Ke: jepter@itmo.by
Kepada: I Made Arsana <madearsana@unesa.ac.id>

Dear Dr. Arsana,

Please find the attached Letter of Acceptance. As to your question regarding the queue, we are not able now to give a definite answer, it depends on many factors.

Best regards,

Editors

НАЦИОНАЛЬНАЯ АКАДЕМИЯ НАУК БЕЛАРУСИ

ИНСТИТУТ ТЕПЛО- и МАССООБМЕНА им. А. В. ЛЫКОВА

ИНЖЕНЕРНО-ФИЗИЧЕСКИЙ ЖУРНАЛ

220072, г. Минск, ул. П. Бровки, 15. Телефоны: (017) 284-21-31, (017) 284-23-31, факс: (017) 232-25-13. Email: jepter@itmo.by. URL: "http//www.itmo.by/jepter.html". Сервер новостей: newsserv@itmo.by (группа sci.ifzh-jepter.news). Индекс 74920 по каталогам РО "Белпочта", агентства "Роспечать", "Издания стран СНГ" национальных агентств.

September 12, 2019

Dear Dr. Arsana,

This is to acknowledge that the paper "Enhanced Heat Transfer Effectiveness Using Low Concentration SiO_2@TiO_2 Core-Shell Nanofluid in Water/Ethylene Glycol Mixture" (reg. number 163-2019) by I. M. Arsana , L. C. Muhimmah, G. Nugroho, and R. A. Wahyuono has been accepted for publication in the Journal of Engineering Physics and Thermophysics.

Managing Editor

Larissa Shemet

UNESA Mail

I Made Arsana <madearsana@unesa.ac.id>

RE: Manuscript Submission (163-2019)

Jepter <jepter@itmo.by> 20 Januari 2021 17.40
Kepada: I Made Arsana <madearsana@unesa.ac.id>

Dear Dr. I Made Arsana,

Now I, as an Editor of the Journal of Engineering Physics and Thermophysics, prepare your paper "ENHANCED HEAT TRANSFER EFFECTIVENESS USING LOW CONCENTRATION SiO_2–TiO_2 CORE–SHELL NANOFLUID IN WATER/ETHYLENE GLYCOL MIXTURE" for publication. In this connection, I would like to ask you to answer a few my attached questions.

Best regards,

Editor

From: I Made Arsana [mailto:madearsana@unesa.ac.id]
Sent: Saturday, January 09, 2021 5:42 AM
To: Jepter
Subject: Re: Manuscript Submission (163-2019)

Dear Editors,

[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]

About Paper 163-19.pdf
65K

Dear Dr. I Made Arsana,

Now I, as an Editor of the Journal of Engineering Physics and Thermophysics, prepare your paper "ENHANCED HEAT TRANSFER EFFECTIVENESS USING LOW CONCENTRATION SiO_2–TiO_2 CORE–SHELL NANOFLUID IN WATER/ETHYLENE GLYCOL MIXTURE" for publication. In this connection, I would like to ask you to answer a few my questions:

1. You twice use in the first paragraph in **Materials and Method** the phrase "The particles ~~where~~ were extracted from the reaction solution by centrifugation (3000 rpm, 6 min) and redispersed in 25 mL ethanol by ultrasonication for 30 min. " Does this mean that such a process was carried out twice?
2. Please, explain what are:

   Pr_s in Eq. (4), k_w in Eq. (6), k_f in Eq. (7), h_i and h_0 in Eq. (8), and A in Eq. (9). These quantities are absent in **Notation**.
3. In what units is the intensity given in Fig. 2b?

You should not send a new variant of the paper, only send your answers. Thank you in advance.

Best regards,
Valeria Leitsina, Editor

UNESA Mail

I Made Arsana <madearsana@unesa.ac.id>

RE: Manuscript Submission (163-2019)

I Made Arsana <madearsana@unesa.ac.id> 23 Januari 2021 05.14
Kepada: Jepter <jepter@itmo.by>

Dear Dr. Valeria Leitsinia,

Editor of The Journal of Engineering Physics and Thermophysics,

In response to your questions for our manuscript, please find the following answers addressing your queries:

1. No. We apologize in advance and please omit/remove the sentence "The particles were extracted from the reaction solution by centrifugation (3000 rpm, 6 min) and re-dispersed in 25 mL ethanol by ultrasonication for 30 min" which comes first in the paragraph (page 2, line 27 – 29).

2. Pr_s in Eq. (4) is the static Prandtl number calculated for the average of the inlet and outlet temperatures.

k_w in Eq. (6) is conductive heat transfer coefficient of nanofluids ($W{\cdot}m^{-1}{\cdot}K^{-1}$)

k_f in Eq. (7) is conductive heat transfer coefficient of air ($W{\cdot}m^{-1}{\cdot}K^{-1}$)

h_i and h_0 in Eq. (8) are convective heat transfer coefficient of nanofluids and convection coefficient of air ($W{\cdot}m^{-2}{\cdot}K^{-1}$), respectively.

A in Eq. (9) is total heat transfer area in normal direction (m^2)

3. The unit of intensity in figure 2b is "counts" (number of X-ray photon diffraction)

Many thanks in advance for the suggestion to correct mistakes in our manuscript.

Best regards,

I Made Arsana

[Kutipan teks disembunyikan]

Letter for Editor .pdf
88K

Dear Dr. Valeria Leitsinia,

Editor of The Journal of Engineering Physics and Thermophysics,

In response to your questions for our manuscript, please find the following answers addressing your queries:

1. No. We apologize in advance and please omit/remove the sentence "The particles were extracted from the reaction solution by centrifugation (3000 rpm, 6 min) and re-dispersed in 25 mL ethanol by ultrasonication for 30 min" which comes first in the paragraph (page 2, line 27 – 29).

2. Pr_s in Eq. (4) is the static Prandtl number calculated for the average of the inlet and outlet temperatures.

   k_w in Eq. (6) is conductive heat transfer coefficient of nanofluids ($W \cdot m^{-1} \cdot K^{-1}$)

   k_f in Eq. (7) is conductive heat transfer coefficient of air ($W \cdot m^{-1} \cdot K^{-1}$)

   h_i and h_0 in Eq. (8) are convective heat transfer coefficient of nanofluids and convection coefficient of air ($W \cdot m^{-2} \cdot K^{-1}$), respectively.

   A in Eq. (9) is total heat transfer area in normal direction (m^2)

3. The unit of intensity in figure 2b is "counts" (number of X-ray photon diffraction)

Many thanks in advance for the suggestion to correct mistakes in our manuscript.

Best regards,

I Made Arsana

UNESA Mail

I Made Arsana <madearsana@unesa.ac.id>

RE: Manuscript Submission (163-2019)

Jepter <jepter@itmo.by> 4 Januari 2021 18.45
Kepada: I Made Arsana <madearsana@unesa.ac.id>

Dear Dr. I Made Arsana,

In the near future we'll begin to prepare your paper “ENHANCED HEAT TRANSFER EFFECTIVENESS USING LOW CONCENTRATION SiO_2@TiO_2 CORE-SHELL NANOFLUID IN WATER/ETHYLENE GLYCOL MIXTURE" (reg. number 163-2019)

for publication in the Journal of Engineering Physics and Thermophysics. As prescribed by the Springer Publishers, please sign the attached Consent to Publish, then date, scan the Consent and send the scanned PDF file to our address.

We’ll connect with you if we have some questions during editing.

With best regards,
Editors

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Title of article**:**

NAMES OF ALL CONTRIBUTING AUTHORS:

Corresponding author's signature:

Corresponding author's name:

Date:

I Made Arsana <madearsana@unesa.ac.id>

RE: Manuscript Submission (163-2019)

I Made Arsana <madearsana@unesa.ac.id> 9 Januari 2021 10.42
Kepada: Jepter <jepter@itmo.by>

Dear Editors,

The first time I thank you for my paper will be published in the near future. I hereby attach the Consent.

Best Regards,

(Dr. I Made Arsana)
Department of Mechanical Engineering, Universitas Negeri Surabaya, East Java, Indonesia 60231
Phone: +6281230004262
+6282245760098

[Kutipan teks disembunyikan]

Consent-I MADE ARSANA.pdf
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Journal Title in Russian: **Inzhenerno-fizicheskii zhurnal**

Title in English: **Journal of Engineering Physics and Thermophysics**

Title of article**: ENHANCED HEAT TRANSFER EFFECTIVENESS USING LOW CONCENTRATION SiO_2@TiO_2 CORE-SHELL NANOFLUID IN WATER/ETHYLENE GLYCOL MIXTURE**

NAMES OF ALL CONTRIBUTING AUTHORS: I. M. ARSANA, L. C. MUHIMMAH, G. NUGROHO, R. A. WAHYUONO

Corresponding author's signature:

Corresponding author's name: I.M. ARSANA

Date: 09 JANUARY 2021

I Made Arsana <madearsana@unesa.ac.id>

RE: Manuscript Submission (163-2019)

Jepter <jepter@itmo.by> 11 Januari 2021 21.56
Kepada: I Made Arsana <madearsana@unesa.ac.id>

Dear Dr. I Made Arsana,

This is to confirm the receipt of the CONSENT.

With best regards,
Editors

From: I Made Arsana [mailto:madearsana@unesa.ac.id]
Sent: Saturday, January 09, 2021 5:42 AM
To: Jepter
Subject: Re: Manuscript Submission (163-2019)

Dear Editors,

[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]

UNESA Mail

I Made Arsana <madearsana@unesa.ac.id>

OFPRINT-942(15)

Jepter <jepter@itmo.by> 29 Maret 2021 18.57
Kepada: madearsana@unesa.ac.id

Dear author,

Please, find attached the offprint of your paper published in No. 2, Vol. 94, 2021.

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With best regards

Editorial Board

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