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Study the Effect of SiO_2 Nanofluids on Heat Transfer in Double Pipe Heat Exchanger

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Abstract: *In this paper the effect of nanofluid is studied in the double pipe heat exchanger counter current flow, the viscosity of nanofluids are measured at different temperatures and different particle sizes. SiO_2 nanoparticles are dispersed at different concentrations (0.2-2) % with different particle sizes of (50-25) nm in base fluid of water. The friction factor and heat transfer coefficient are calculated at different nanoparticle sizes, the results showed that the viscosity was increased as nanoparticle concentration increased. The friction factor is increased as SiO_2 nanoparticles concentration and increased as nanoparticles size decreased. The heat transfer coefficient increased as nanoparticle concentration increased and particles size decrease.*

Keywords*: nanofluids, heat exchanger, viscosity, friction factor*

1.Introduction

Efficiency in transferring the heat and minimizing the heat waste represent main concerns in the industrial applications. Nanofluids are widely used to enhance the heat transfer rate. Nanofluids represent a suspension of the nanoparticles in certain base fluids. Considering their properties, they have different ones compared with the already known mixtures of solid-liquid combinations. The excellent chemical and physical properties of these mixtures made the nanofluids to be used in a wide application of heat transfer enhancing processes [1-3].

Usually the metal oxides of nanoparticles have better thermal properties than the base fluids [4-7]. Choi in 1995 used the nanoparticles for the first time [3, 8, 9]. Choi found that when adding solid particles with sizes less than 100 nm, the thermal conductivity of the nanofluids increased higher than the base fluid [3, 10].

Pen˜as *et al.* [11] were used the technique of hot- wire that used two types of nanoparticles SiO_2 and CuO in water and ethylene glycol to measure the thermal conductivity. They used different weight fraction up to 5%, the results showed that the thermal conductivity of nanofluids have good results. Namburuet *et al.* [12] were used another types of nanoparticles SiO_2 with different particle sizes (20, 50, 100) nm to calculate the viscosity and specific heat of nanofluid with ratio 60:40 water and ethylene glycol base fluid; giving a new correlation employing experimental data. Another research studies the effect of volume concentration and the temperature to measure the viscosity of TiO_2/water nanofluid. The range of temperature was between 25 to 70 °C with fraction of 0.1, 0.4, 0.7 and 1% as in [13]. A spiral coil of five turns made of copper tube which used to investigate the nanofluid of different volume fraction of (0.01, 0.025, and 0.05) %. The results showed that the Nusselt number increased compared to the base fluid water. The friction factor was also studied and the result showed

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that the friction factor increased as nanoparticle concentration increased, Duangthongsuk, W. [14]. Vajjha R. *et al.* [15] calculate the pressure drop of circular tube for the three types of nanofluids (CuO, SiO_2, and Al_2O_3), the results showed that the heat transfer rate increased as nanoparticles concentration increased and the pressure increased as the volume fraction increased too. SiO_2 and Al_2O_3 nanoparticles dispersed in the base fluid water and the study the heat transfer rate at concentration of (0.5 to 2) % with particles in size of range from 10 to 100 nm as given by Minakov A. *et al.* [16] . Hamid K. *et al.* [17] studied the heat transfer coefficient and the friction factor of TiO_2 nanofluid. Zarringhalam M. *et al.* [18] studied the effect of pressure drop and the heat transfer coefficient of CuO nanofluid with water base fluid. The experimental data was collected from a double tube heat exchanger in turbulent flow region. The results showed that at 2% volume fraction the heat transfer coefficient increased by 57%. Yarmand H. *et al.* [19] used graphen nanoparticles in turbulent flow region of a rectangular pipe. The heat transfer coefficient and the friction factor increased 19.68% and 9.22% for 0.1%volume fraction. In this paper silicon oxide nanoparticles are used two range of particle sizes of (50 &25) nm, synthesis in the base fluid water at different temperatures in double pipe heat exchanger under turbulent flow region, to study the effect of nanoparticles in viscosity, friction factor and heat transfer coefficient of SiO_2 nanofluids at different concentrations.

2.Materials and methods

2.1.Experimental setup

Double pipe heat exchanger made of stainless steel is used to study the effect of nanofluids on the friction factor in the heat exchanger. The nanofluids enter the outer pipe of 30 cm in diameter with a range of temperatures (15, 20, 25, and 30) °C. Steam at 120°C enters the inner pipe of diameter 15 cm. The pressure is measured by gage and the temperature of outer fluid is recorded by thermocouples which are fixed at the inlet and outlet of cold and hot streams. Figure (1) shows the heat exchanger used in this research.

Figure 1. The experimental work, general view of the installation

2.2. Preparation of nanofluids

Silicon dioxide nanoparticles are in the form of white powder from (M K Impex Crop., USA) with two particle sizes (50 and 25) nm. The SiO_2 nanoparticles are added to the water base fluid at different weight fraction (0.2-2) %. The nanofluids prepared by second method, nanoparticles are synthesized into water by mixing with mixer at speed of 300 rpm. Then the nanofluids are stabilized by sonication (MTI Corporation made in USA) it for 20 min to enhance the stability of nanofluid prepared.

2.3.The expressions used

The expression Blasius H. [20] is used to calculate the coefficient of friction of the nanofluid with silicon dioxide of different weight fraction has the form (1), and for the Nusselt number the Dittus Boelter relation is used in the form (3):

$$f = 0.3164 \cdot Re^{-0.25};\tag{1}$$

$$\mathrm{Re} = \frac{\rho d u}{\mu};\tag{2}$$

$$Nu = \frac{h}{k}d = 0.023\mathrm{Re}^{0.8}\mathrm{Pr}^{0.4}.\tag{3}$$

3.Results and discussions

3.1.The effect of weight fraction of nanofluids

The viscosity of nanofluids is measured at different temperatures (15, 20, 25, 30) °C by viscometer (ASTM D445). The results showed that the viscosity increased as nanoparticle weight fraction increased. This is agreed with Ahmet B. D., 2019 [21] as shown in Figures below.

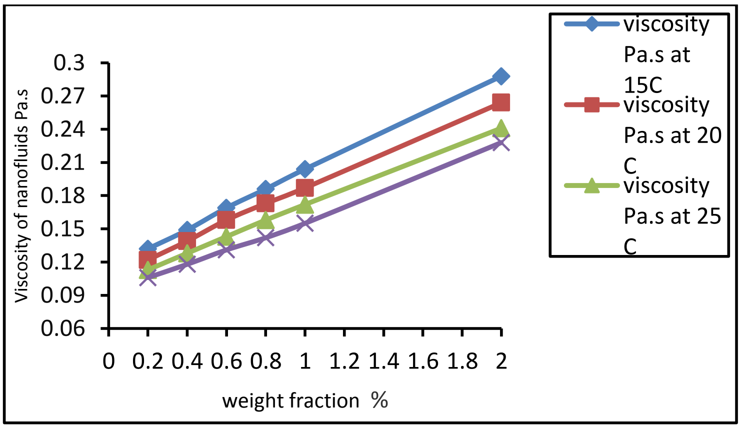

Figure 2. The viscosity of nanofluids at different temperatures

The friction factor of SiO_2 nanofluid increased as weigh fraction increased at different temperatures (15, 20, 25 and 30) °C as shown in Figures 3, 4, 5 and 6. This is agreed with Azmi W.H., 2017 [22].

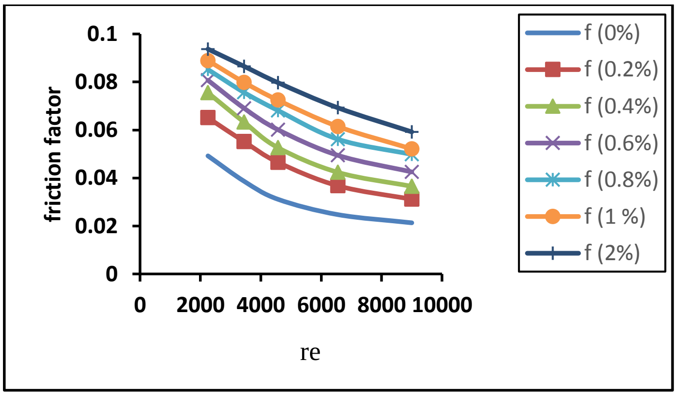

Figure 3. The friction factor at different weight fraction of SiO_2 at 15°C

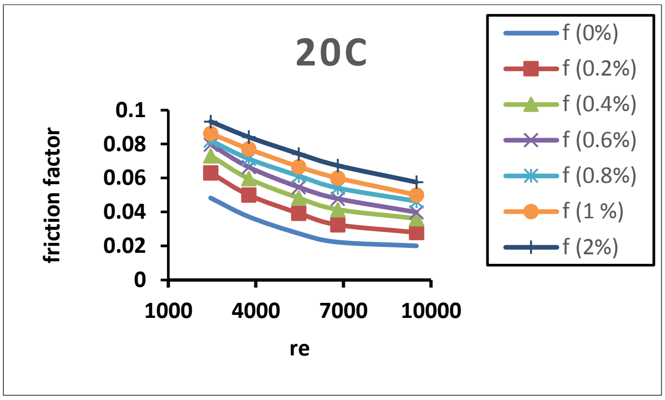

Figure 4. The friction factor at different weight fraction of SiO_2 at 20˚C

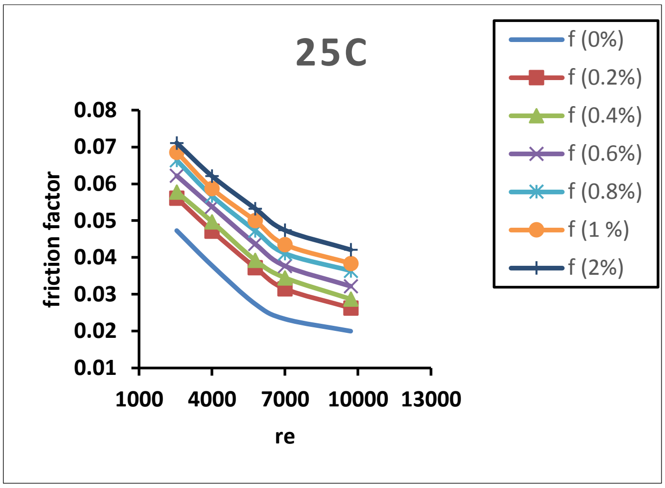

Figure 5. The friction factor at different weight fraction of SiO_2/water at 25˚C

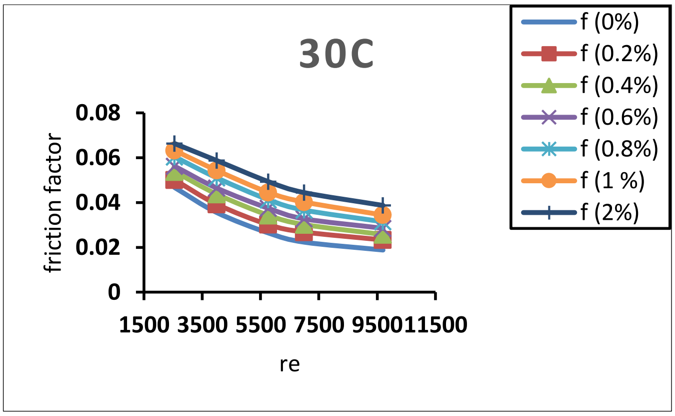

Figure 6. The friction factor at different weight fraction of SiO_2 at 30˚C

The heat transfer coefficient of SiO_2/water increased as nanoparticle weight fraction increased for different inlet temperatures as shown in Figure 7. The results are agreed with Devdatta P. and [23, 24].

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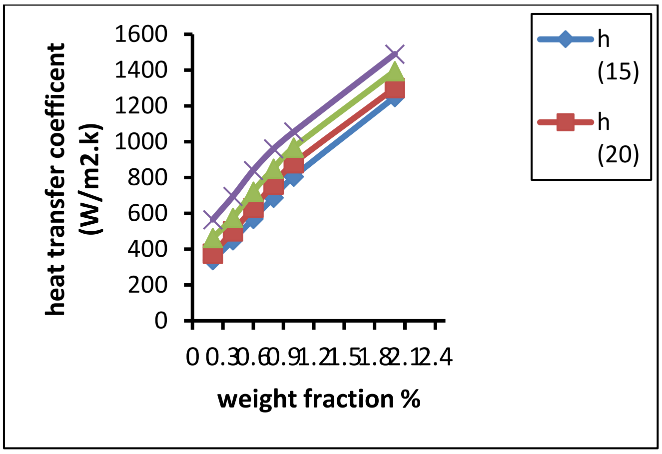

Figure 7. Heat transfer coefficient of SiO_2/water nanofluids at different temperatures

3.2.The effect of particle size of nanoparticles

The friction of SiO_2 nanofluids with (50 and 25) nm particle size are calculated. The friction of SiO_2/water of 50 nm had lower value in friction factor compared to SiO_2/water of 25 nm particle size. Figure 8 shows the friction factor of two particle size at 25 $^{\circ}$C temperature degree. This is agreed with Suad H. D., 2018 [25].

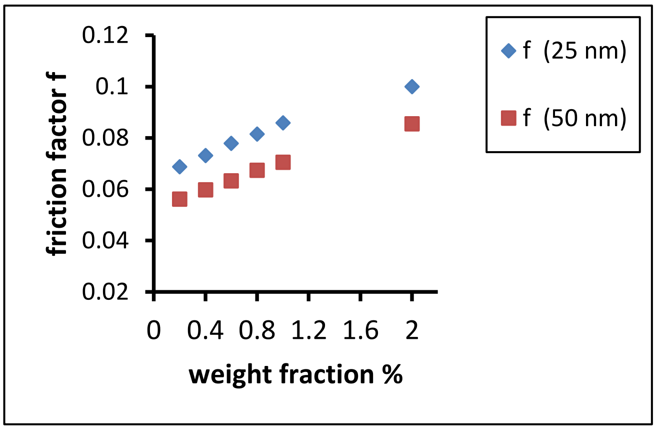

Figure 8. Friction factor of SiO_2/water nanofluid at two particle sizes (25 and 50) nm

The size of nanoparticles particles influences the value of heat transfer coefficient; the particle size of 25 nm SiO_2 has a higher heat transfer value than the particle size of 50 nm, of the same concentration. Figure 9 shows the heat transfer coefficient of 2% concentration at 25°C temperature degree. This is agreed with Vivekanand L. K., 2017 [25].

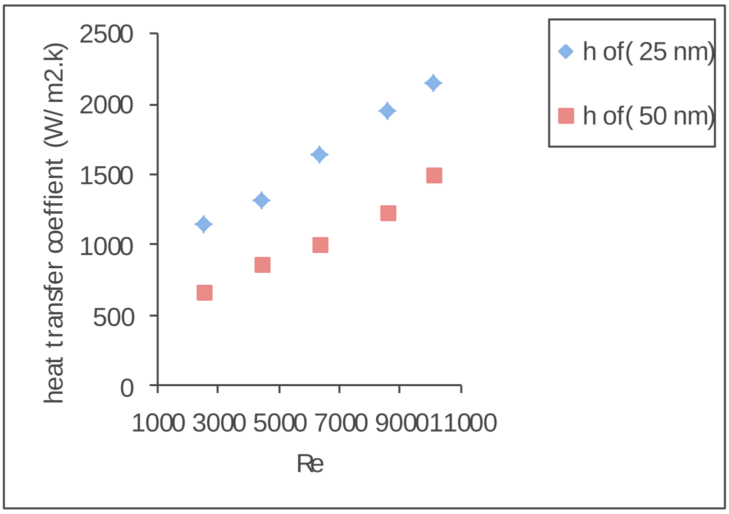

Figure 9. Heat transfer coefficient SiO_2/water nanofluid of two particle size (25 and 50) nm at 2% concentration and 25˚C

4.Conclusions

The viscosity of SiO_2/water nanofluids increased as weight fraction increased, this is because of the distribution of SiO_2 nanoparticles in the base fluid water. The viscosity SiO_2/water nanofluid decrease as temperature of inlet fluid.

The friction factor increased as nanoparticle concentration increased because of the increasing in viscosity for different inlet temperature. The friction factor increased by 42% to the base fluid water at weight fraction 2% and 30°C.

The heat transfer coefficient increased as the concentration of SiO_2/water nanofluids with different temperature. This increment by 75% for 2% weight fraction and 30°C.

The friction factor of 25 nm particle size has high value of friction than the 50 nm. This is due agglomeration of nanoparticles in the flowing stream.

The heat transfer coefficient increased as nanoparticle size increased too. The nanoparticles of 25 nm size have higher value of heat transfer coefficient than the particle size of 50 nm. This is because of the high surface area of SiO_2 nanoparticle to enhance the heat transfer rate of nanofluids.

NOMELECTURE AND GREEKSYMBOLS

Symbol	**Description**	**Units**
d	Diameter of the inner tube heat exchanger	m
f	Friction factor	-
h	Heat transfer coefficient	W/ m^2.K
k	Thermal conductivity	W/m.˚C
Nu	Nusselt number	$Nu = \frac{hd}{k}$
Pr	Prandtle number	$\Pr = \frac{\mu Cp}{k}$
Re	Reynolds number	$\mathrm{Re} = \frac{\rho ud}{\mu}$
T	Temperature	˚C
u	Fluid velocity	m/s

Units	**Description**	**Symbol**
ρ	Density	kg/m^3
μ	Dynamic viscosity	kg/m.s

Symbols	**Description**
f	Base fluid
nf	Nanofluid
p	Nanoparticle

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