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Research Article

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Investigation of heat transfer and friction factor of Al_2O_3 nanofluid inside shell and tube heat exchanger

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Abstract In the present paper, experimental study is performed to investigate Nusselt number and friction factor of nanofluids through a shell and tube eaxchnger. The Nusselt number of the Al_2O_3–water nanofluid flowing through a shell side. Experiments are conducted with a volume fraction between 0.1 %, 0.2 %, and 0.3 % and Reynolds number between 3000 and 10500. Experimental results observed that, the heat transfer enhancement with the increase in a Reynolds number or nanoparticle volume fraction. Experimental measurement also shows the Nusselt number with high nanofluid concentration is improved by 35 % of base fluid for low Reynolds number.

Keywords Nusset Number, Nanfluid, Al_2O_3, finned tube, heat exchanger.

1. Introduction

Heat exchangers are mechanical devices which used to transfer a thermal energy, also called enthalpy, through thermal contact between two or more fluids, between a solid surface and a fluid, or between solid particulates and fluid, at different temperatures [1, 3]. In addition, no external heat or work interactions required in heat exchangers which are commonly used in heating or cooling specific fluid stream. Also, heat exchangers are used in condensation and evaporation of single or multi-component fluid streams [2,4].

General examples of heat exchangers are shell and tube exchangers, automobile radiators, condensers, evaporators, air pre-heaters, and cooling towers. Although, sensible heat exchanger will have no phase change occurrence in any of processed fluid [5]. Furthermore, some exchangers such as Electric heaters and nuclear fuel elements could contain internal thermal energy sources. Particular kinds of heaters such as Boilers, fired heaters, and fluidized-bed exchangers engage chemical interaction and combustion inside the exchanger [6].

Nguyen et al. [7] studied coefficient of heat transfer and characteristic of Al_2O_3 nanoparticles fluid flow dispersed in water flowing via microprocessors liquid cooling system under a turbulent flow condition. According to Nguyen et al, the Nano fluid shows higher heat transfer coefficient compared to the base liquid. Also, the Nano fluid with a 36 nm particle diameter show higher heat transfer coefficient in comparison to the Nano fluid with a 47 nm particle diameter.

He et al. [8] conducted an experimental study to test TiO_2-distilled water Nano fluids heat transfer performance and flow characteristics. Flow of Nano fluids was through a vertical pipe in an upward direction under a constant heat flux boundary condition in both a laminar and a turbulent flow regime. Results revealed that heat transfer coefficient at a known Reynolds number and particle size is raised with increasing nanoparticle concentration in both laminar and turbulent flow regimes.

P.C. Mukeshkumar et al. [9] conducted an experimental study using Al_2O_3 / water Nano fluid. On both parallel and counter flow shell configuration and helically coiled tube heat exchanger. This experiment was achieved by altering the parallel flow configuration into counter flow configuration under laminar flow regime. By using two step methods The Al_2O_3 water Nano fluid at 0.4% and 0.8% particle volume concentration were prepared. The total heat transfer coefficient was 5-9% higher than that of parallel flow at 0.8% Nano fluid.

Numerous studies are conducted to increase the performance characteristics of the shell and tube heat exchanger in order to get maximal benefit from it. Im et al [10] perform an experiment to test the performance of the shell and tube heat exchanger with three different Nano fluids, which are ZNO-W, Al_2O_3-W and SiO_2-W. Overall heat transfer coefficient enhanced by 35% for ZNO-W, while enhanced by 32% for Al_2O_3-W, and 12% for SiO_2-W. In addition, heat transfer coefficient for ZNO-W, Al_2O_3-W and SiO_2-W enhanced by respectively. Moreover, actual heat transfer for ZNO-W, Al_2O_3-W and SiO_2-W enhanced by %, 32% and 26% respectively.

Albadr et al [11] (2013) states that Heat transfer via heat exchanger using Al_2O_3 nano fluid at different concentration. Also, they state that forced convective heat transfer coefficient is a little higher than that of base liquid at same mass flow rate and inlet temperatures. According to Kwon, Kim and Li C G [12] presented study regard usage of ZnO and Al_2O_3 Nano fluids, their final results states that heat transfer coefficient increased to 30% at 6% volume concentration of Al_2O_3 Nano fluid.

Frad et al states that [13] "Numerical and Experimental Investigation of Heat Transfer of Zno/Water Nano-fluid in the Concentric Tube and Plate Heat Exchangers". Experiment was conducted on plate and concentric tube heat exchangers, which tested by using both water-water and Nano-fluid-water streams. In addition, The ZnO/water (0.5 v/v%) nano-fluid was used as the hot stream. Final experimental result reveal that both heat transfer coefficients and heat transfer rate of the Nano-fluid in both heat exchangers are higher than base liquid such as water. Moreover, the effectiveness of the plate heat exchange is higher than concentric tube heat exchanger.

Arun Kumar Tiwari [14] conducts as experiment to test Thermal Performance of Shell and Tube Heat Exchanger by using Nano fluids. Experiment involve using cold water based Nano fluids flow through a tube side and water as hot fluid flows through a shell side. As a result, Usage of nanoparticles in water based Nano fluid as coolant will improve the effectiveness considerably. Furthermore, heat transfer coefficient is increased by more 3% Al_2O_3 nanoparticles in water based fluid.

This paper carried out to investigate the effect of nanoparticles (Al_2O_3) concentrations on heat transfer and frication factor shell and tube heat exchanger. Three nanofluid consternations (0.1 %, 0.2 %, and 0.3 %) were used as a working fluid. The Reynolds number varied from 3000, 4500, 7500, 9000, and 10500. The heat exchanger tube are used with and without fine.

2. Experimental Set-up

The experimental set-up sketched in Fig. 1 was constructed to determine the heat transfer and pressure drop through a finned tube heat exchanger.

Figure 1: Photo of Experimental Set-Up

This includes two lop, one is cooling lop and through in finned tube. The second one is heating lop, which through shell side. The cooling lope consisted of cooling tank (5 L), compressor (5 kW). On the other hand the heating loop consisted of: heating tank 3 L. this tank used to mixed the nanoparticles with distilled water. The nanofluid was heating by two heaters each is 2.5 kW. The cooling and heating fluids are pumped by two centrifugal force pumps 0.45 Hp. The flow rate of nanofluid (heating fluid) and cooling fluid are measured by two digital flow meters. The inlet and outlet temperature of shell and finned tube heat exchanger are measured by used four RTD temperature transducer. While the pressure drop through the shell side is measured by pressure transducer fixed in inlet and outlet of shell, as shown in Fig. 2.

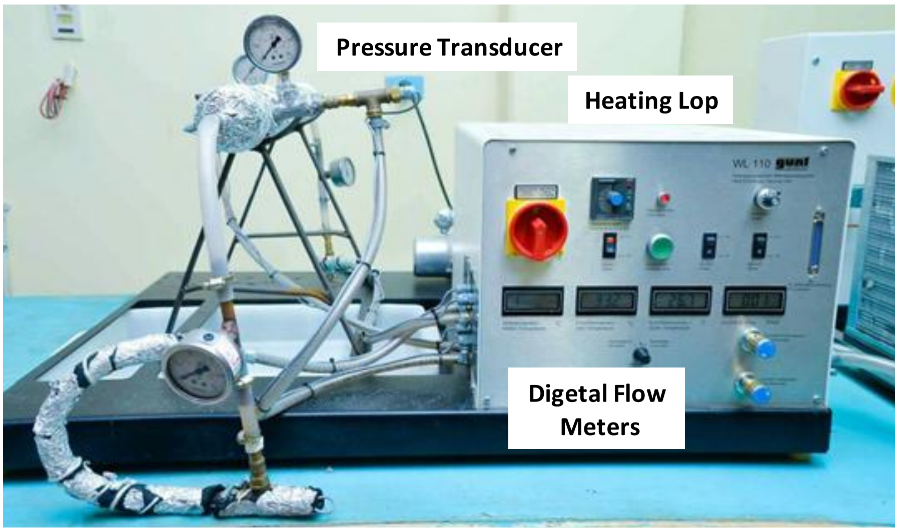

Figure 2: Photo of Shell and Finned Tube Heat Exchanger

2.1. Finned Tube

During this study used shell and finned tube heat exchanger, two models are used. One tube without fine the other model of tube used with fine. The dimension of tube is 1000 mm length, inner diameter is 12 mm with thickness of 1.5 mm. the tube with fine is consist of thirteen fins are fixed at tube with pitch between them is 50 mm, each fin is 40 mm diameter with thinks of 2 mm, as shown in Fig. 3.

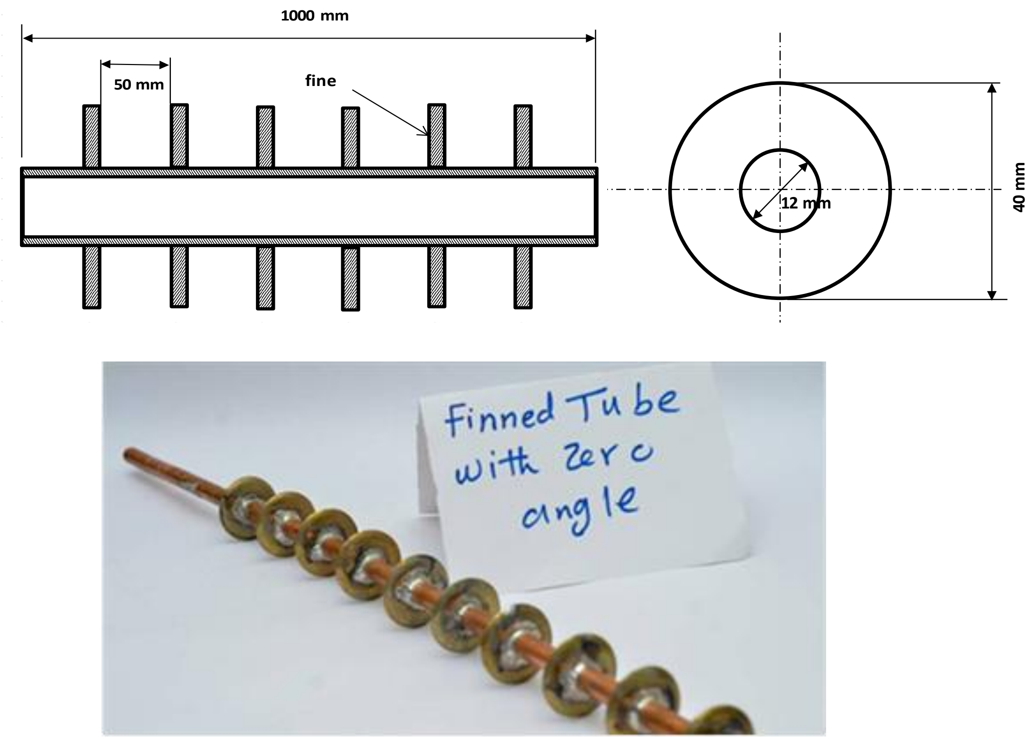

Figure 3: View of tube with fine (no scale)

3. Data Reduction

The amount of heat through a heat exchanger can be calculated via various Methods such as LMTD method and NTU method:

3.1. LMTD Method

The log mean temperature difference (LMTD) could be written for a parallel flow or counter flow arrangement. The LMTD has the form:

$$\Delta T_{LMTD} = \frac{\Delta T_2 - \Delta T_1}{1n\,\frac{\Delta T_2}{\Delta T_1}} \qquad (1)$$

Temperature difference at heat exchanger each end is represented by ΔT1 and ΔT2 either flow is parallel or counter. The LMTD expression assumes that the total heat transfer coefficient is constant alongside the entire flow length of heat exchanger. If it is not occurred, in that case an incremental analysis of heat exchanger is needed. When cross flow correction factor is used, The LMTD method will be applicable to cross flow arrangements.

The heat transfer rate for a cross flow heat exchanger described as:

$$Q = F\ UA\Delta TLMT\ D \qquad (2)$$

According to the counter flow heat exchanger arrangement the factor F is a correction factor, and the log mean temperature difference. In LMTD both inlet and outlet temperatures are identified. While this is not the case, the explanation of heat exchanger trouble becomes to some extent tedious. An alternate method based upon heat exchanger efficiency is more suitable for this type of analysis. If ΔT1= ΔT2= ΔT, then the expression for the LMTD reduces simply to ΔT.

4. Results and Discussion

4.1. Nusselt number

Fig. 4 show the Nusselt number distribution against Reynolds number with two type of tube one without fine and other with fine. It observed that, the Nusselt umber in increase with increase Reynold number for two cases of tube. In addition the Nusselt number increases with finned tube. Where the value of Nusselt number is 32.6 and 37.9 al low Reynolds number for tube without and with fine respectively. While fro high Reynolds number (Re = 10500), the value of Nusselt number increase to 67.7 for tube without fine and 76.9 for tube with fine. This results due to increase of heat transfer area with finned tube as shown in Fig. 4.

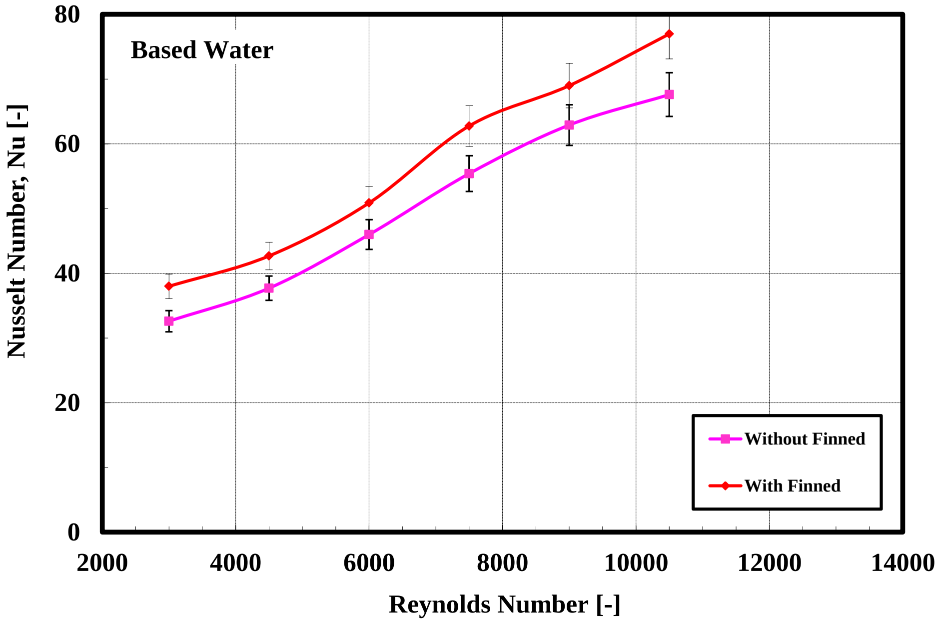

Figure 4: Nusselt number distribution with Reynolds number for with and without finned tube at based water

Fig. 5 and Fig. 6 show the Nusselt number distribution with difference of nanfluid concentrations for two cases finned tube and tube without fine. It observed that, the Nusselt number increase with increase of nanofluid for two cases. Where the Nusselt number increase for 0.3 % increase by 35 % compared with based water at low Reynolds number (Re = 3000). While for high Reynolds number (Re = 10500) the increase of Nusselt number for 0.3 % nanofluid is reduction to 25.6 % compared with based for case of tube without fine as shown in Fig. 5. For case of finned tube, the improved of Nusselt number is 16 % for 0.3 % nanofluid compared with based water at low Reynolds number (Re = 3000). While the improved of Nusselt number is 11.8 % at high Reynolds number (Re = 10500). From the previous decision, the enhancement of Nusselt number is better for tube without fin than those of tube with fine as shown in Fig. 6. This result is due to, for case of tube without fine, the Brownning motion is free. Where the fins in finned tube are opposition the nanoparticle move this cause low of improvement of Nusselt number.

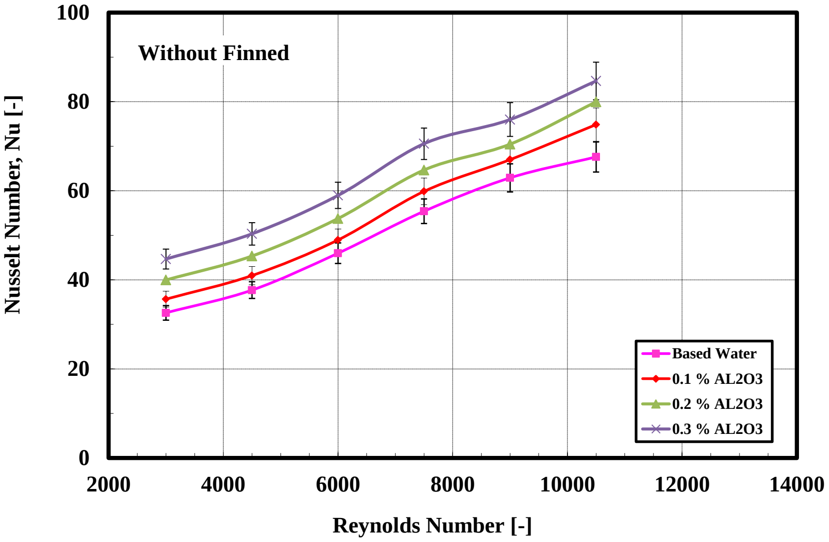

Figure 5: Nusselt number distribution with Reynolds number for nanofluid concentrations for tube without fine

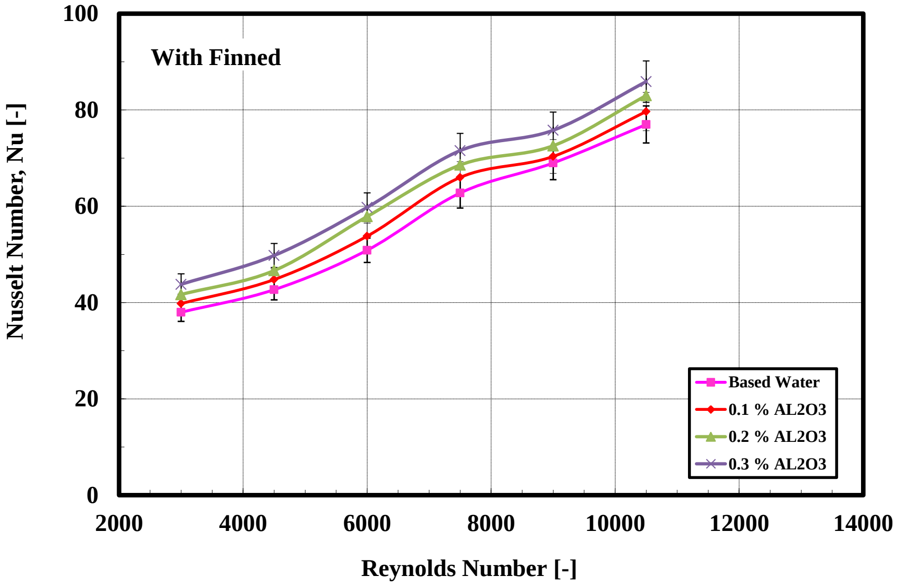

Figure 6: Nusselt number distribution with Reynolds number for nanofluid concentrations for tube with fine

4.1. Fraction factor

The fraction factor calculates from pressure drop which measured directly from pressure transducer. Fig. 7 illustrates the frication factor distribution with Reynolds number for two case of tube with and without fine for based water. It observed that, the frication factor is decrease with increase of Reynolds number for two cases. In addition, the frication factor is increase with finned tube. Where the value of frication factor of tube with fine is 0.081 while is 0.078 for tube without fine at low Reynolds number (Re = 3000). For case of high Reynolds number the value of frication factor is 0.043 and 0.038 for with and without fine respectively as shown in Fig. 7.

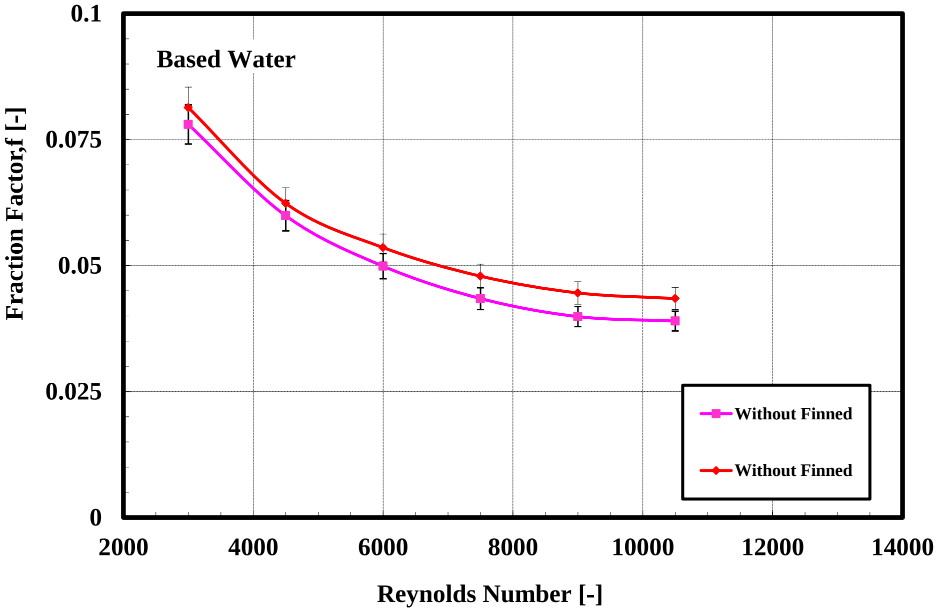

Figure 7: Fraction factor distribution with Reynolds number for with and without finned tube at based water

The effect of nanofluid concentration on frication factor for tube with and without fine is shown Fig. 8 and Fig. 9. These figures showed the frication factor for two cases increases with increase on nanofluid concentration. This result is due increase of hydraulic properties (density and viscosity) of nanofluid. Where the value of frication factor at 0.3 % nanofluid concentration increase by 7.8 % compared with based water at low Reynolds number. For high Reynolds number, the increased raise to 28.9 % for case of tube without fine as shown in Fig. 8. For tube with fine the value of frication factor at low Reynolds number is 0.081 and 0.086 for based water and nanofluid concentration of 0.3 % respectively. For high Reynolds number the value become 0.053 and 0.043 for based water and nanofluid concentration of 0.3 % respectively as shown in Fig. 9.

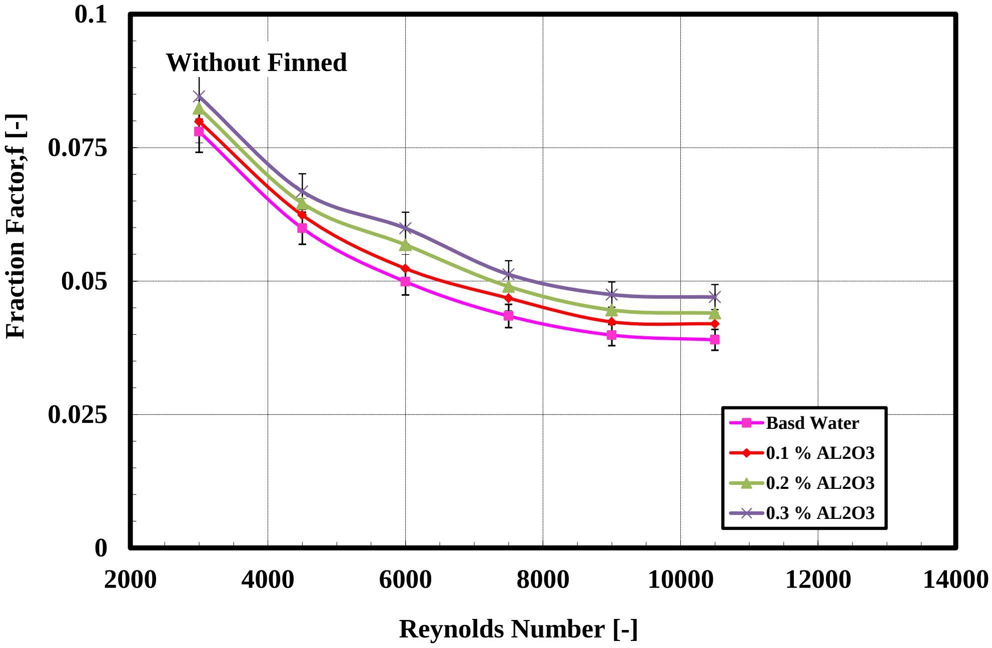

Figure 8: Fraction factor distribution with Reynolds number for nanofluid concentrations for tube without fine

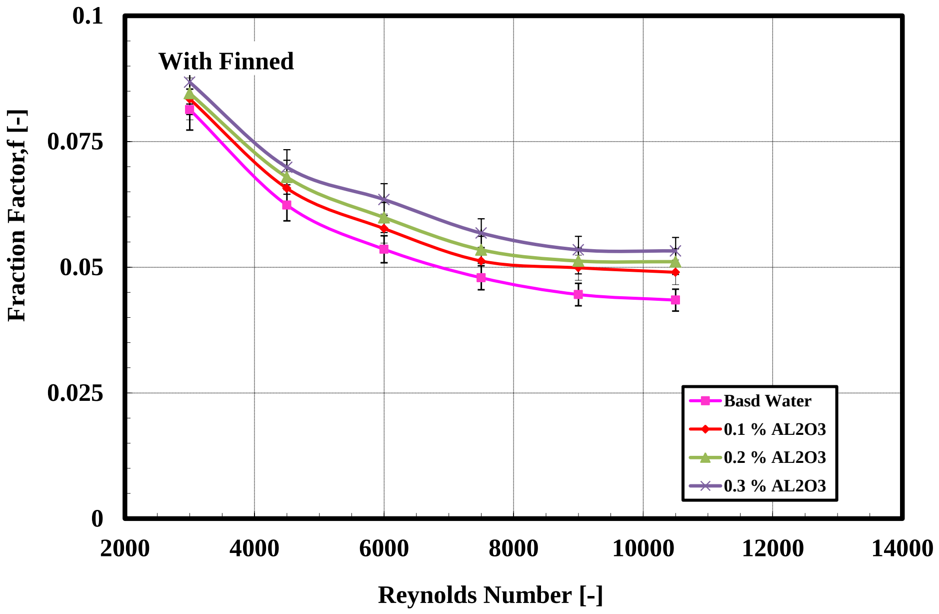

Figure 9: Fraction factor distribution with Reynolds number for nanofluid concentrations for tube with fine

5. Conclusions

Experiments were performed to investigate the Nusselt number transfer and frication factor of an Al_2O_3/Water nanofluid mixture containing alumina nanoparticles flowing in shell and tube heat exchanger. The Reynolds number are barred from 3000 to 10500, also the nanofluid concentration are changed 0.1 %, 0.2 %, 0.3 %. The conclusion from this study could be summarized by the flowing:

- Nusselt number frication factor are influence by nanolfuid concentration. Where both of Nusselt number and frication factor transfer increase with increase of nanfluid concentration.
- Nusselt number is enhancement with increase of Reynolds number, causes increases of turbulent intensity.
- At high nanofluid concentration (0.3 %) the improvement of Nusselt number 25.6% for case tube without fine. For case of tube with fine the improved in Nussedt number is reduce to 11.8% for high Reynolds number (Re = 10500) and high nanofluid concentration of 0.3 %.
- The of Nusselt number improvement for finned tube, while the frication factor is increase when used finned tube also.

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