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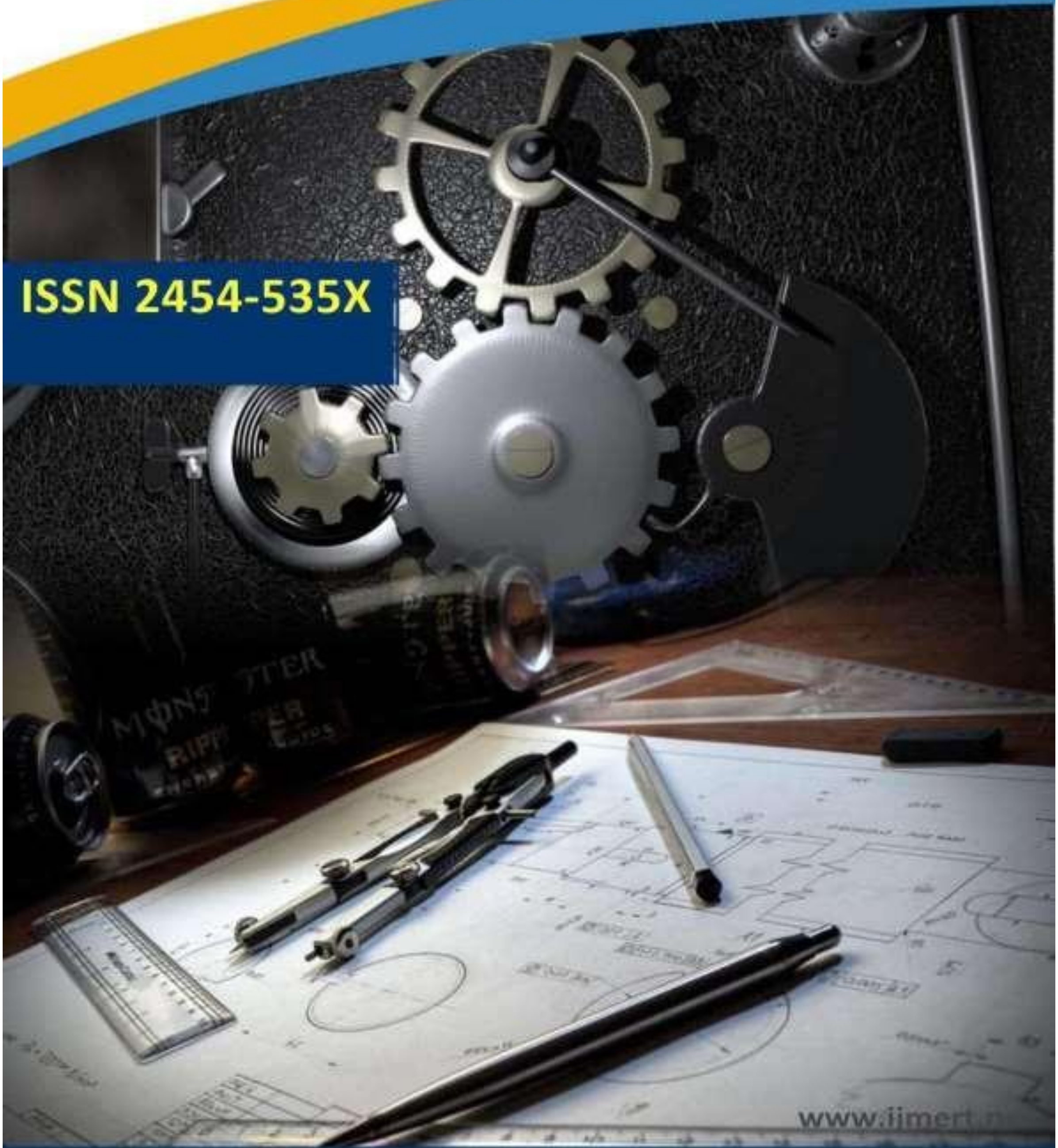

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Experiment on the Forced Convection and Friction Factor of Nanofluid in Downward Flow in Slope Pipes

Rama krishna Rao[1], Rambabu Rao[2] & vishwanath[3]

[†]Department of Physics, Southeast University, Nanjing 211189, China

[‡]Department of Hydraulics and Heat Engineering, Don State Technical University, Rostov on Don, 344002, Russia

[††]Faculty of Physics, Semnan University, Sokkan Park, Semnan, 3513119111 Iran

Email: farhad.hekmatipour@gmail.com, Tel: +79514932263

ABSTRACT: The influence of nanofluid on forced convection and friction factor in downward flow in slope pipes is studied using copper oxide - thermal oil nanofluid. Accordingly, the flow's shape is fully developed, and the tube's isothermal wall serves as another boundary condition. Prantle number is used to examine the effects of solid-fluid, negative slope, and forced convection. When the mass concentration of nanoparticles rises, the outcomes of forced convection somewhat improve. In this article, it is suggested to use a few formulae to assess forced convection and pressure drop in downhill flow under contact wall temperature and fully developed flow. The maximum variance, or 18%, is acceptable for experimental research that can be used in manufacturing. the forced convection rate and pumping power rate that go together

KEYWORDS: nanofluid; Pressure drop; Force convection; downward flow; laminar flow

INTRODUCTION

It is acceptable for researchers that the most of advanced industries, such as air-conditioning and petrochemical, oil and gas, require forced convection because the pump should be used to determine the pressure which is needed in main line. The improvement of the forced convection is capable to be beneficial on the declination of energy waste and size of the heat exchanger. Not only, they used to enhance convective heat transfer but also heat losses decrease in heat exchangers. In fact, the lack of research on single phase flow in downward flow can be observed the majority of researches have been done on two- phase flow in downward flow have been down [1-5]. It is very important to know the behavior of single-phase fluid in downward flow because the downward flow is used in industrial usages such as automobile and microelectronic. Another point is that nanofluid does not investigated in downward flow which can help us to cool fluids which has high temperature in industries. The outcomes demonstrate that nanofluids are more beneficial than normal ways in order to improve heat transfer. Because the nanoparticles' Brownian motion which augments the velocity profile uniformity raises share wall stress. Initially, the concept of stable nanoparticle suspension was employed by Choi and Eastman [6] to generate a modern kind of solid- liquid. It is clear that several studies have been done to analyze the impact of using nanoparticle on heat transfer and thermal conductivity in different situations [7-16].

Ho et al. [10] applied Al_2O_3-water nanofluid throughout a circular tube. They focused on the changing pressure drop, Nusselt number, and entropy generation. The outcome of research exposes forced convection and pressure drop. Qi et al. [11] implemented a study on forced convection of TiO_2-water nanofluids in the spirally fluted and a circular tube. It is presented that the forced convection in a spirally fluted tube was greater than circular tube. Over a twenty-year period, several types of research have been implemented to figure out the impact of nanofluids with high Prandtl number on forced convection in horizontal pipes [17-25]. Due to determining best suspension of nanofluid, three kind of nanoparticles like copper dioxide, titanium dioxide, and aluminum dioxide were mixed with turbine oil [24]. The outcome of estimation exposes that Nusselt number increases with the increment in nanoparticle's mass concentration. Even though, the outcome illustrates nanofluid which content copper oxide which are more reliable than Al_2O_3 and the improvement of heat transfer of copper oxide nanofluid is better than Al_2O_3 nanofluid. Over the last seven years, several types of research were widely conducted to determine the influence of

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inclination angle of tubes and reverse flow in slope tubes [25-33]. This is because it presumes the heat transfer augments with inclination angles. Akhavan-Behabadi et al. [25] applied water-based carbon nanofluids to measure

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convection and pressure drop of MWCNT-water nanofluid in a vertical smooth tube. The measurement illustrates that the Darcy friction factor of nanofluid is greater than base fluid and does not rise substantially with rising of the weight mass fraction.

Although several sorts of research have been executed to set up the impact of downward two-phase flow in variant geometry tubes [34-37], a number of investigations which have been performed on downward single-phase flow in tubes are really few [38]. Fershtman et al. [38] employed heat flux, downward liquid flow rate, and IR thermography to analyze the forced convection of water in test pipe. Measurements at different vertical locations along the heated foil were performed to downward water flow rates and heat fluxes in the tube. The effect of downward flow on mixed convection under steady state and heat flux in the tube is investigated by Fershtman et al [38]. The Reynolds number range covers all flow regime in the pipe. The upshot demonstrates that the augmentation of slope is able to rise the natural convection under stable states and heat flux. Sheikholeslami et al. [39] studied on effect of Lorentz forced-convection nanofluid flow over a stretched surface. They illustrates temperature index magnetic, velocity ratio, radiation parameters, nanoparticle volume fraction can effect on temperature and velocity distribution. Muhammad et al. [40] applied several magnetic nanofluid to determine rate of heat transfer in boundary layer [41]. Muhammad and Nadeem [42] performed a numerical investigation to determine the performance of nanofluid on forced convection in boundary layer flow regime. They used ferromagnetic nanofluid to analyse heat transfer in boundary layer. Sheikholeslami et al. [43] work on heat and mass transfer characteristic of unsteady nanofluid flow between parallel plates. They confirmed Brownian motion and rheological properties has effect on heat transfer. Saleem et al. [44] did a numerical research on mixed convection boundar layer flow of upper-convected Maxwell fluid with Cattaneo- Christov heat flux model. Sheikholeslami et al. [45] employed Cu-water nanofluid to do a study on heat transfer characteristics of a stretching permeable cylinder. The result illustrate that skin friction coefficient rises with rise of Reynolds number and suction parameter but it decrease with rise of nanoparticle volume fraction. Akbar NS, and Mustafa MT [46] worked to obtain the effects of copper nanoparticles for blood flow and the result of copper-blood and copper-water. Hosseini et al. [40] applied lattice Boltzmann method to study on natural convection flow using nanofluids in square enclosure with partially heated walls. The inclination angle rose from 0º to 80º in this investigation. Muhammad et al. [47] sought to investigate on the effect of magnetic dipole on a thermally stratified ferrofluid past a stretchable surface. The result shows that heat transfer rate decrease. Nadeem et al. [48] studied on the influence of Caattaneo-christov heat flux model in a viscoelastic fluid flow saturated with a porous medium. Saleem et al. [49] did an analytical investigation on find combined convectional three dimensional flow of an upper convected Maxwell fluid in the presence of magnetic field and heat generation/absorption effects. The result shows that increase of Deborah number β is happened with velocity decrease. Muhammad et al. [50] performed a numerical investigation because squeezing flow of viscous fluid with heat and massfluxes using Cattaneo–Christov theory should be developed. Nadeem et al. focused on the effects of heat transfer phenomenon in a ferrofluid in presence of a magnetic dipole. Muhammad et al. [51] investigated the thermally stratified phenomenon and stagnation point.

Most experiments on forced convection and Darcy friction factor of nanofluid are limited to horizontal and reverse flow in the tube and they do not consider downward flow in the pipe. The limited investigations have been down in downward flow in the pipe while many manufactures use the downward flow in heat exchangers to cool the fluids having high temperature. It is a big problem which do not know about the effect of cooling in downward flows in pipes and there is no longer distinguishable method to decrease the heat transfer. So, it seems to be valuable to know that the effect of using nanofluid in downward flow because this method can be replaced with other type of method in industrial usages. Understanding the

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use of nanofluid in downward flow which is beneficial or which is not suitable seems to be very valuable. Another problem can be considered that there is no equation which presented the nanofluid heat transfer in downward inclined tube. Indeed, there is no longer investigation on the effect of nanofluid in downward flow in pipe. Indeed, the greater part of correlations introduced to assess the mixed convection in inclin d tube are not ready to approve the forced convection of nanofluid flow in inclined tube. Experimental research has been done to determine the impact of nanofluid on forced convection [52-57]. Hekmatipour et. al
[58] worked on the effect of nanofluid on convective heat transfer in downward flow in tube have been down. The result showed that the use of nanofluid and downward flow can be effective on the improvement of heat transfer in downward flow. It is pioneer paper which is presented to determent the effect of adding nanoparticle and downward flow because this paper determines the method is beneficial or not. The objective of this project is the determination of using nanofluid and downward flow can help us to improve the convective heat transfer under constant wall temperature. Because the most of manufactural usages needs a method for enhancing convective heat transfer in downward flow in industrial applications. There are a couple of numerical articles which are qualified to predict the experimental result. Sometimes, the numerical outcomes are against experimental results [59, 60]. Therefore, numerical model is not displayed in this research. Therefore, the introduction of correlation in downward flow is valuable. The impact of using copper oxide-thermal oil nanofluid and inclination angle on the convective heat transfer and pressure drop in the slope circular tube is analyzed empirically. The boundary condition is really important in experimental analysis. Thus, the flow regime was fully developed and wall of tube was isothermal

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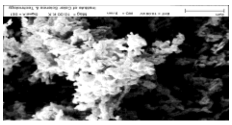

EXPERIMENT IMPLEMENTATION

Nanofluid features

In this empirical study, the original size of nanosolid particles (CuO) and the purity of nanosolid particle (CuO) were 40nm, and 99%, respectively. SEM (Scanning Electron Microscope) is used to show image of the nanosolid particle. The image of nanoparticles is observed in Fig. 1. Irregular forms is observed in Fig. 1. An ultrasonic UPS400 device which has frequency of 24 kHz and the power of 400W is employed. This is due to making a homogeneous and a comparative permanent nanofluid. According to the experiment, three suspensions of thermal oil-copper oxide particles with the weight concentration of 0.5%, 1%, and 1.5%. The nanofluids were permanent for 216 hours, after 216 hours, the nanoparticle commenced to sediment and settled down entirely for 14 days. Thermo-physical features of the thermal oil and copper oxide nanoparticles are exposed in Table 1 and Table 2, respectively. The outcome of rheological properties of nanofluids which are employed for experiment are presented [14].

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Figure 1. SEM image of the Copper Oxide nanoparticles

Table 1. Rheological characteristics of the thermal oil

Rheological property	Temperature (°C)	
	38	100
ρ (kg/m^3)	855	815
Cp $(kJ/kg.K)$	2.03	2.30
P (m^2/s)	32×10^{-6}	5.2×10^{-6}
k (W/m.K)	0.133	0.128
Prandtl number	395	76

Table 2. Rehological characteristics of CuO nanoparticles

Rheological property	Value
Morphology	Nearly irregular shapes
Particle size (nm)	40
Purity (%)	99
Bulk density (kg/m^3)	790
True density(kg/m^3)	6400
SSA (m^2/g)	20
Thermal conductivity $(WW/m.K)$	20

Empirical facility

Because forced convection and Darcy friction factor of nanofluid are analyzed experimentally, the empirical facility was established and the schematic figure of device is exposed in Fig. 2. The circulation of flow has various parts consist of the pre- cooling device, test tube, storing tank, gear pump, differential manometer, flow meter, flow regulator, thermocouples and apparatus of altering slope. In experiments, specifications of slope round pipes are depicted in Table 3. Although, the requirement time for achieving a permanent condition was approximately 15 minutes, and thus the data recording was performed after 30 minutes. The test pipe was well positioned to rotate in a steam tank which holds the pipe wall at a constant temperature of 98ºC. The fiberglass is used for insulation of steam tank to decrease heat losses. Two stages were embedded to cool the nanofluid. Because of the precooling nanofluid, a copper coil was put into the storage tank and cooling water pass from copper coil. As the second cooling stage, a shell-and-pipe heat exchanger is exploited to reduce the nanofluid temperature to 15ºC, using cooling water. After that nanofluids were cooled in the storage tank, a gear pump was used because nanofluid had been sent to the main line. Due to producing several flow rates in main line, a bypass line is embedded to regulate the flow rate in the main line. In fact, speed of gear pump was constant. A globe valve is embedded because the flow rate is adjusted and some of the flow come back to the reserve tank. The laminar regime and fully developed flow are achieved from empirical facility. Due to the measurement of wall temperature, four thermocouples are being joined to the wall of test

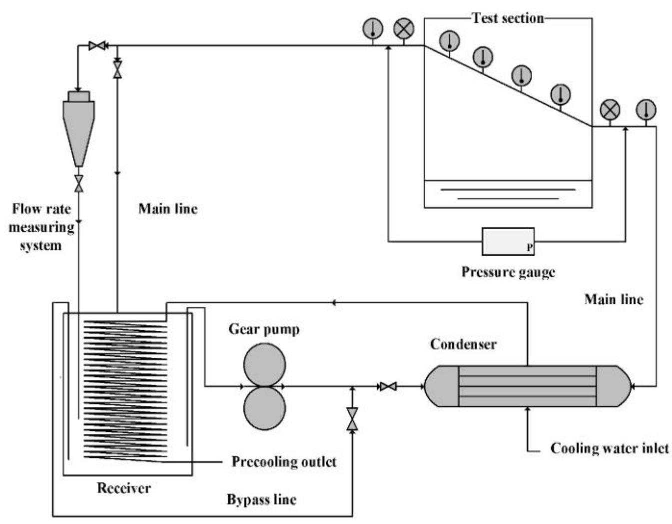

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Figure 2. Schematic of the test setup.

Table 3. Specification of the circular pipes

Parameter	Dimension Circular pipe
Pipe inner/outer diameter (mm)	8.95/9.52
Pipe length (mm)	500
Pipe thickness (mm)	0.42
Angle(º)	-90º<θ<0
Thickness(mm)	0.57

Table 4. The range of Nanofluid flow parameters

Items	**Value**
D/L	0.01784
Pr_{n_f}	330 to 395
Re	180 to 780
T_W (ºC)	98
k (W/m. K)	0.132 to 0.164
Cp (kJ/kg. K)	1.44 to 2.07

Instruments

Because of the measurement of the nanofluid temperature at the inlet and outlet in the test tube, two RTD 100 thermometers were employed with the error of ±0.1ºC. The sensor was put into pipes since sense the central temperature of the fluid at the inlet and outlet pipe. Due to the fact that we analyse the pipe wall temperature, four K-type thermocouples with the SU-105 KPR sensors were utilized with the 100mm intervals, T_1 (100 mm), T_2 (200 mm), T_3 (300 mm), and T4 (400 mm). To protect the thermocouples from the nanofluid flow, they were welded to the outer wall of the pipe. However, the preliminary calculations showed that due to the low thermal resistance of the copper tube wall constract to the temperature gradient in the tube wall is negligible. The temperatures of T_1 to T_4 are, respectively, 98.1, 97.8, 98.0, and 98.1, showing that the pipe wall temperature is almost stable.

A PMD-75 pressure transmitter with the validity of ±0.075% was applied. Here, the flow rate is able to be achieved by gauging the funnel filling time by use of a digital timer with the validity of 0.01s.

The analytical error of the forced convection and Darcy friction factor obtain based on the way introduced in [61, 62] and the outcomes are depicted in Table 5. As is visible, the maximum measurement deflection of the Darcy friction factor, Nusselt number and figure of merit are respectively 9.1%, 9.7%, and 9.8%, respectively. The rheological properties, specification of nanofluids, the empirical data, and classical error are utilised to be calculated the error of empirical data. The error should be computed for specification of nanofluid in different correlations. Then, the error of Nusselt, Figure of Merit and Darcy Friction factor of nanofluid flow is used by specification of nanofluid in downward flow in the pipe.

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Outcome and debate

The Darcy friction factor and the Nusselt number are employed to analyze the pressure drop of Nanofluid flow and forced convection, respectively:(3.1) $_{exp} = \pi^2 \rho D^5 \overline{}_2 \Delta P^{\dot{m}}$ (3.2) $Nu = \frac{\dot{m} C_p}{} \ln \left(\frac{T_w - T_{b,i}}{}\right)^{exp \pi L k T_w - T_{b,o}}$

Because of the estimation of experiments and the acquisition of inaccurate Darcy friction factor and convective heat transfer a Nusselt number of thermal oil in horizontal circular pip, it has provided a comparison between the outcome of experiments and predictable Sider-Tate and Baeher-Stephan [51-54,63] and Hagen- Poiseuile [64-69] models, respectively. The Baeher-Stephan's equation is presented for combined entry flow [65]. The use of thermophysical properties of heat transfer oil and flow condition are presnted in Table 4. The data obtained by the analytical model is compared with the experimental results. Fig. 3 displays the contrast between empirical data and predictable empirical models. The comparison of empirical data with the predictable models of heat transfer of Sider-Tate and Baeher-Stephan are almost 16% and 26%, respectively. Pressure drop is approximately 11%. The difference between empirical data and the classical model are acceptable. The maximum error of experimental data which is lower than 20% of classical experimental correlations, so the results will be reliable [27-30]. Then, experimental results can be use for prediction of experiments in future. The validation of experimental data has been conducted with experimental data [64-69].

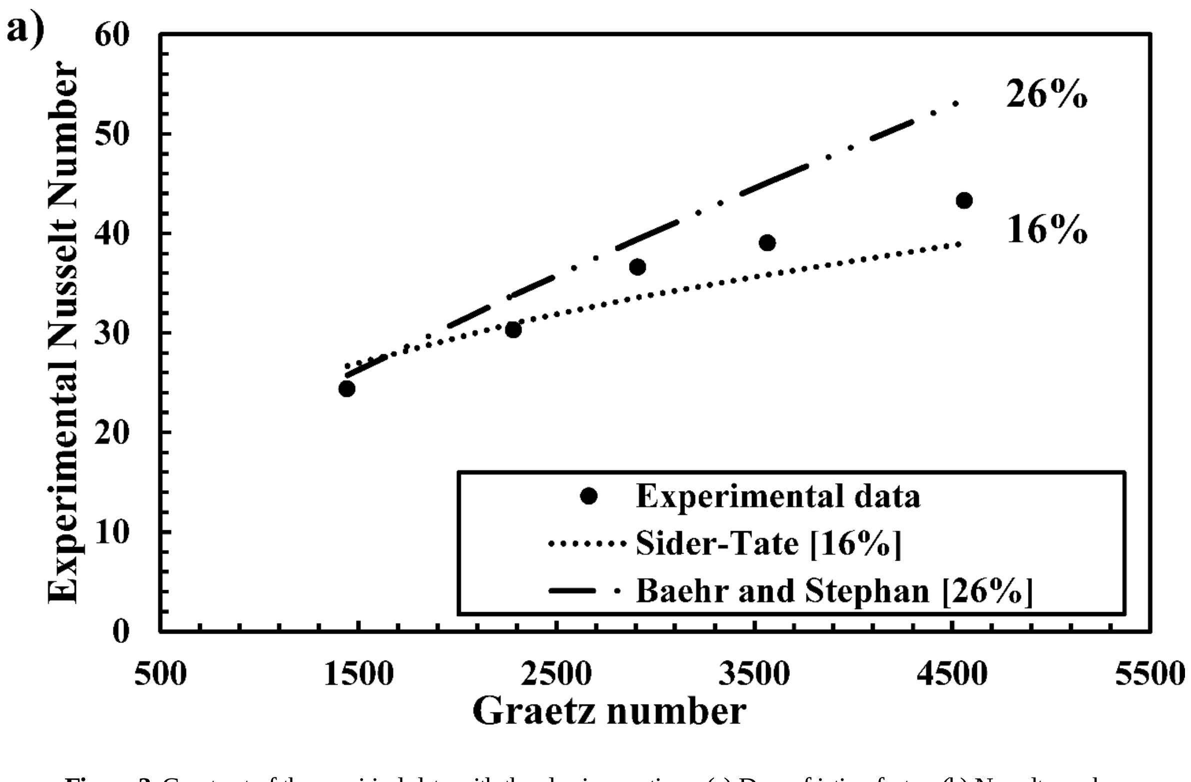

Figure 3. Constract of the empirical data with the classic equations: (a) Darcy friction factor; (b) Nusselt number

Pressure drop

Since the basic fluid and nanofluids have high Prandtl numbers, the flow is fully developed hydraulic. The fully development-length is calculated from $L_e < 0.058 Re_d D$. The peaked fully development-length is 0.396. The results show that the region of haydrulic is in sutiable and the flow is fully development-length. Indeed, the results are in correct region. The line-garphs are plotted by use of Excel and SPSS software and experimental data. In fact, the results were obtained from experimentents and then they were set and drawn with Excel and SPSS. Hagen- Poiseuile [64-69] were used to confirm the friction factor of nanofluids in horizontal tube. The results which are obtained using Hagen- Poiseuile's equation in horizontal tube are acceptable [64-69]. Therefor e, the expereimental results are compared with Hagen- Poiseuile's correlation in Fig. 4. The results show that maximum deflection of empirical data and Hagen- Poiseuile's correlation is not more than 19%. Thus, the

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error of empirical data of nanofluid friction factor is good and the empirical data is able to be used for introduction of a new correlation to evaluate the experimental data in slop tube. In fact, there are a few correlations to be used for the prediction of experimental friction factor in tube; although, the range of correlations do not fit in this project. The range of Reynolds is more than 800 so they could not be used in this project [57, 58]. Fig. 5 depicted the copper oxide – thermal oil (CuO-THO) nanofluid flow friction factor in inclined pipes, the rise of Reynolds number and weight concentration of nanoparticles causes to be increased the Darcy friction factor The reason of Darcy friction factor have a several reason when it used nanofluid and

inclined angle in tube. Becausse of nanoparticle Brownian motion and relative velocity, the declination of the boundary layer and increment of Darcy friction factor were observed. The constant velocity profile and share wall stress increase the Darcy friction factor. It is acceptable for scientists to consider the promotion of density as a factor which effects on the growth of mass concentration. When the downward flow is used the spead of laminar flow is expected to increase sharply and the Reynolds number faces with the increment in downward flow in tube and another reason is mentioned that the Brownian motion may be effective on the increment the spead of flow and the coventive heat transfer which improve moderately. Hence, the Darcy friction factor increases to reach 21% . Since there is no correlation to predict the experimental results of Darcy firction factor of nanofluids in downward flow in circular duct, it is required to introduce an equation to analyze the Darcy friction factor. Based on the empirical data, an equation obtains to be employed for estimation of the Darcy friction factor in downward flow in oblique tube. The Darcy friction factor is able to be obtained according to the Reynolds number, mass concentation, inclination angle, and dynamic viscosity in tube . The equation which is advised to use for friction factor of copper oxide-thermal oil nanofluid flow is as followed:

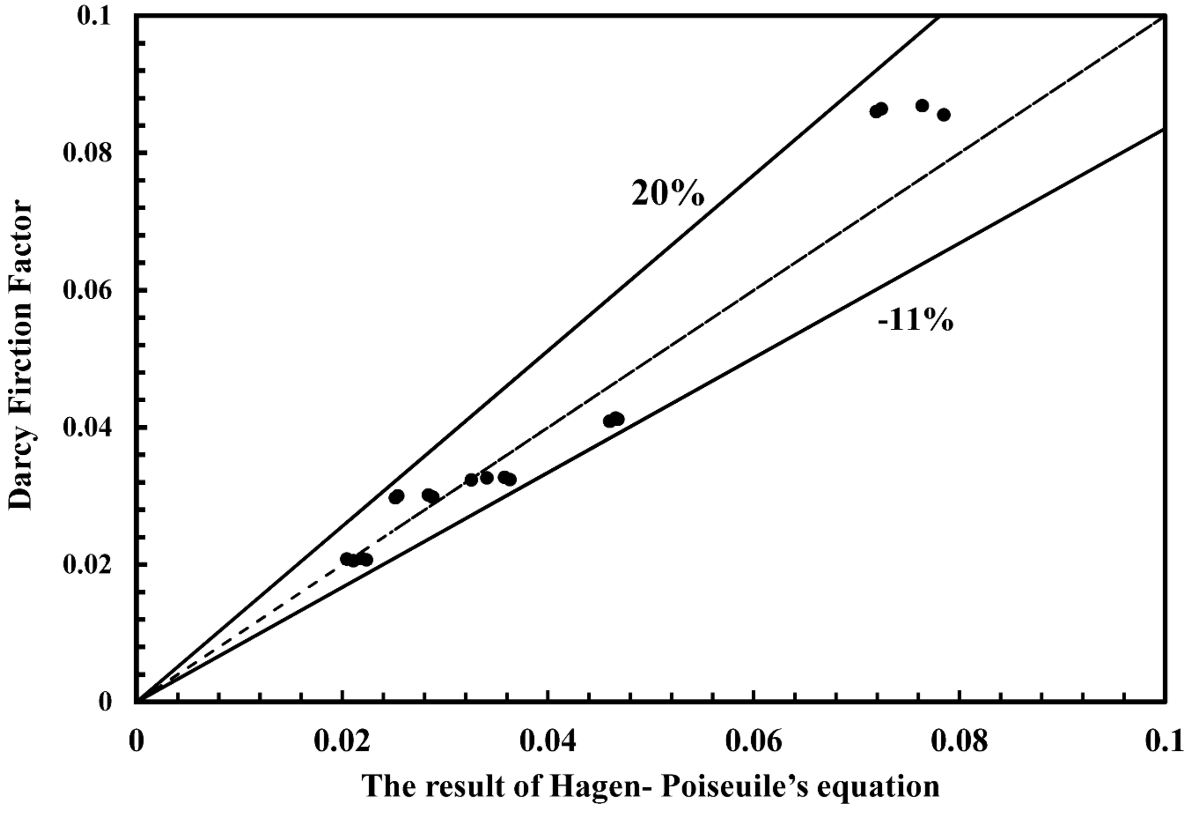

Figure 4. Construct of the empirical data with Hagen- Poiseuile' correlation in horizontal tub

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b)

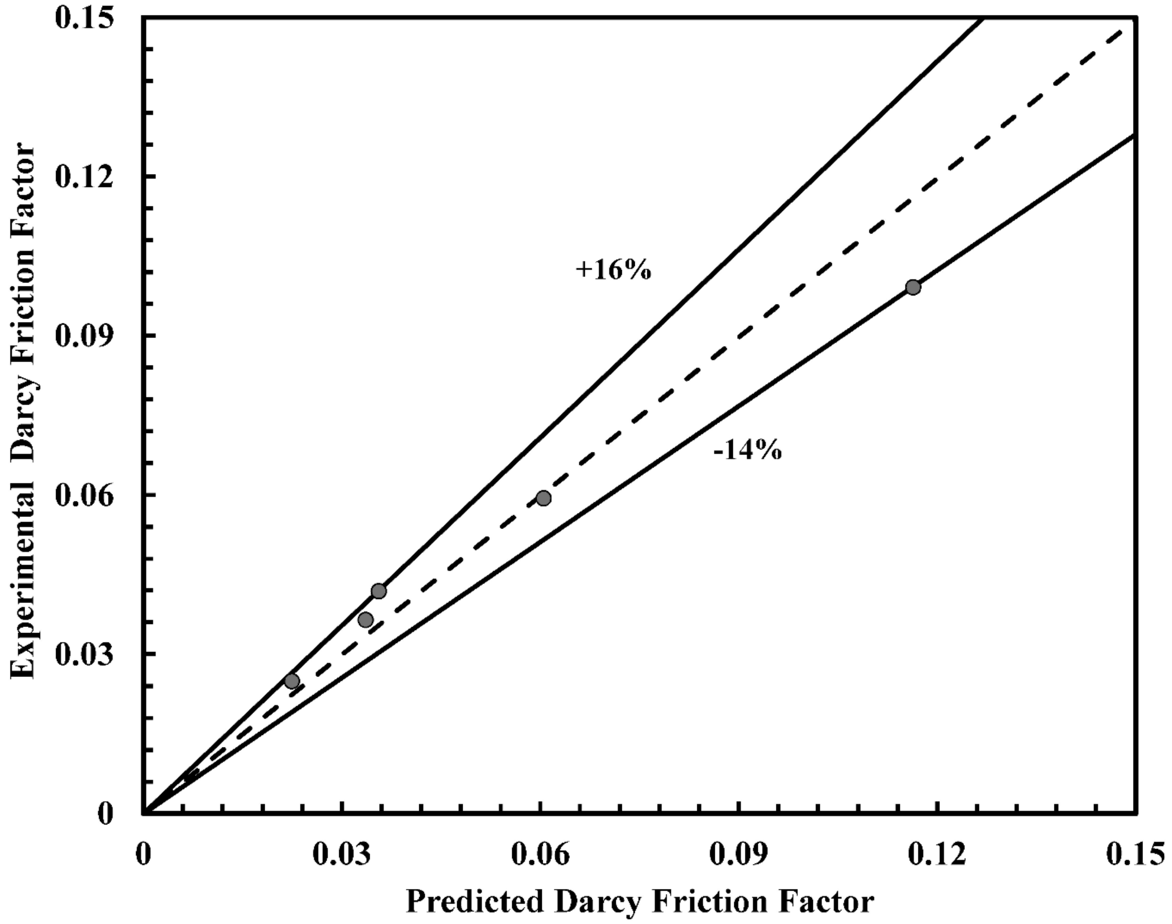

Figure 5. Friction factor based on Reynolds number

(3.3) $$\frac{f_{n_f}}{f_{b_f}} = 0.68(1 + \cos(\theta\theta))^{0.1}(1 + \varphi)^{0.2}(1 + (Re)^{0.14})^{0.9} \left(\frac{\mu_b}{\mu_{ww}}\right)^{0.14}$$

The equation validates for $0 < \varphi < 1.5\%, 0 < \theta\theta < 90$,180<Re<780, 330<$Pr_{nf}$<395. The Darcy friction factor of CuO-HTO nanofluid is calculated by use of slope, mass concentration, Reynolds number and dynamic viscosity ratio. According to [65], the correlation can be defined due to the fully hydraulic development-length in this article. The experimental data and square method was used to determine the correlation in this research article [65]. The square method is used for introducing correlation in this research job. A comparison between the results of the experiments and anticipated the value is shown in Fig. 6. It is distingushable that the peak aberration of the equation is relatively 16%. Thus, the introduced equation is capable to estimate the upshot of experimental Darcy friction factors. It is a useful equation because the influence of mass concentration, Reynolds number, inclination angle, and dynamic viscosity are applied in this correlation. Although several papers and books were studied to obtain a classical correlation, the classical equations are not extracted. Thus, it seems this formula is prototype in a downward single-phase flow in slope circular tubes.

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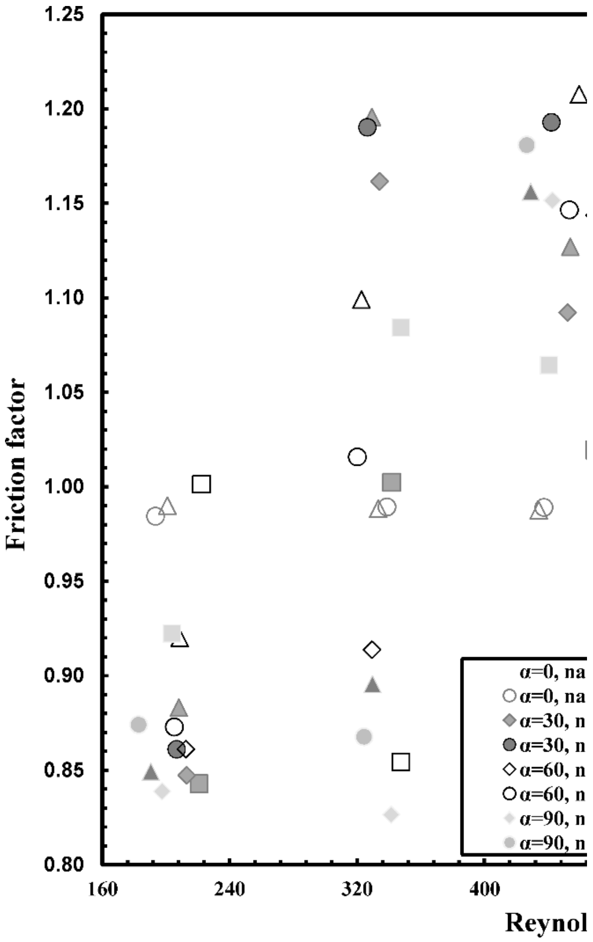
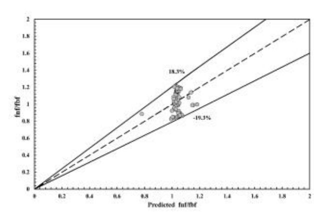


Figure 6. Constract of the experimental Darcy friction factor of the nanofluid flow with the prediction of Eq. (4) inside slope pipe (α=0, -30, -60, -90)

Heat Transfer

Because thermally development-length of thermal oil and nanofluid is calculated by use of Prandtl number and Reynolds number, the correlation which is needed to compute thermally development-length is $L_e < 0.058RePrD$. The peaked thermally development-length is 3.07 m. Prandtl number of fluid plays an important role in determination of fully thermally development-length flow in tubes. As a result, high Prandtl number of fluids, especially oil, can effect on the increment of fully thermally developed flow. This means that the most of correlations which are showed are in developing regime [51-56, 64-69]. To create thermally fully development-length in test section, the length should not be less than 30 meters in nanofluid flow under constant wall temperature. Actually, the lack of financial resources and space needed to rotate tube in laboratory. Thus, The results are presented in developing region [69, 70]. The line-graphs are plotted by use of Excel software, SPSS, and experimental data extracted form experimental facility. After the result of experiments is obtained. The software is used to be drawn the line-graphs and SPSS is gained to be determined the equation and using square method is calculated the experimental model to be presented in this article. Not only it is acceptable that adding nanoparticle to base fluid caused increment in forced convection, but also altering slope may increase forced convection in pipe [35]. The comparison between experimental result and experimental correlation is shown in Fig. 7 [69, 70] in horizontal tube. The deviation from experimental data and experimental correlations [69, 70] is lower than 18%. Correlations are presented for fully thermally developed flow in horizontal tube, the result shows that experimental data are reliable and this means that experimental data are accurate. This is a method for evaluating of the result of experiments and the basic results compare with classical equations which are accepted by different scientist in this subject. Fig. 8 shows that the maximum Nusselt number is happened in nanoparticle weight concentration 1.5%, inclination angle of -30, and Reynolds number 780. In fact, the result in inclination angle of -30 increases

because the spead increases modrately and Browanian motion of nanoparticle in nanofluid has an effective on the increment of convective heat transfer. But, the fist reason is that the velocity of fluid is not increased dramatically in inclination angle -30º while the time of passing nanofluid in test tube decrase modrately, so the convective heat transfer enhances slowly in other angles like 60º. Fig. 8 shows the influence of using nanofluid on forced convection of the nanofluid flow in downward flow in slope tubes. The changing angle and Brownian motion may alter the shape of flow or make the vortex flow. This is the reason why boundary flow declines in downward flow in slope tube. According to experiments, an equation defined to assess the effectiveness of nanofluids forced convection in downward flow in a circular pipe,it is as followed:



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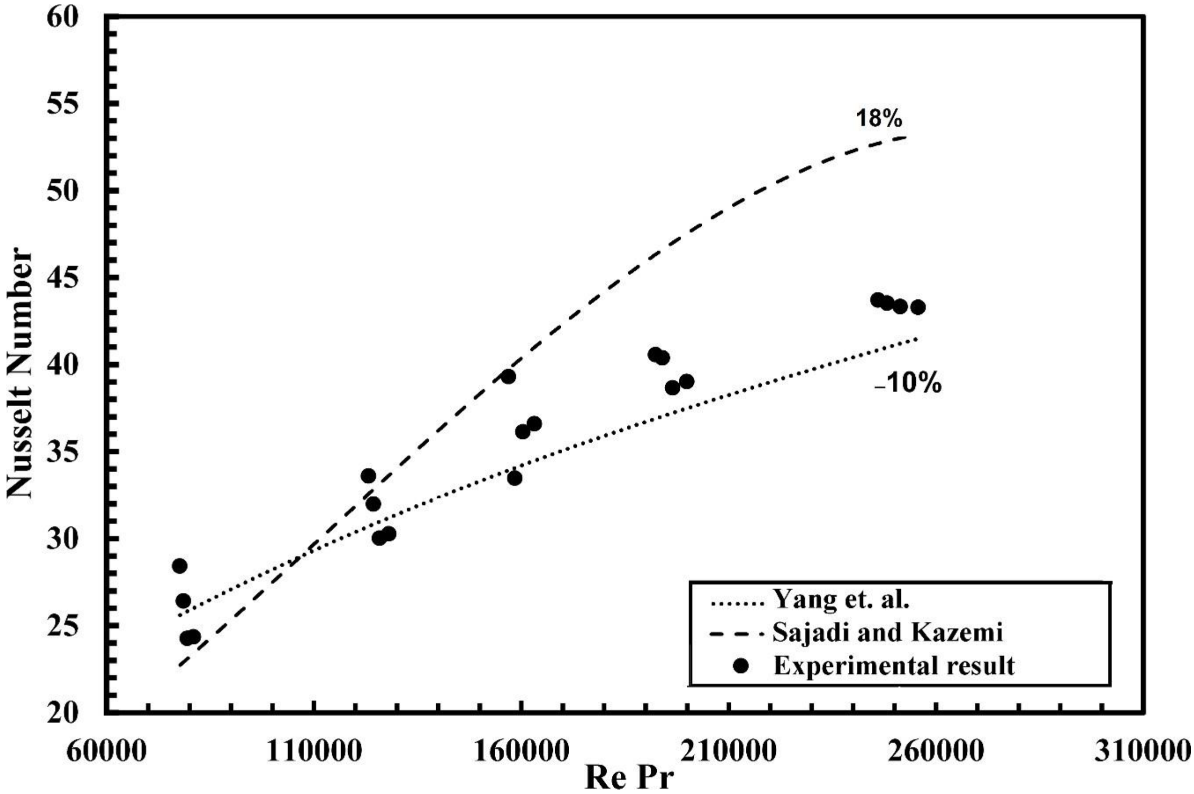

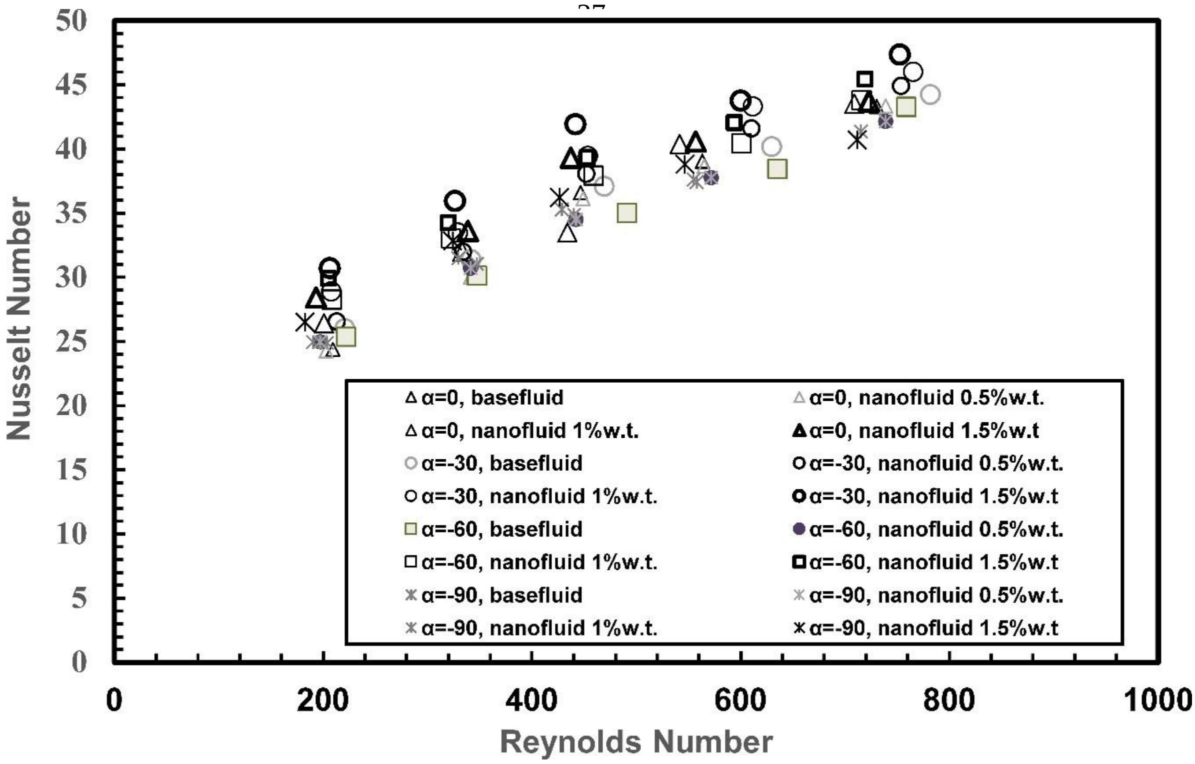

igure 7. The comparison the experimental data in horizontal tube with Yang and Sajadi –Kazemi's correlations in horizontal tube

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Figure 8. The use of CuO nanoparticles effect on the Nusselt number in downward flow in oblique tubes (3.4)

$$_{nf}= 4.2(1 + \cos\theta\theta)^{0.2}(1 + \varphi)^{0.1}Re^{0.3}\left(\frac{\mu_b}{\mu_{ww}}\right)^{0.14}$$

The equation validates for $0 < \varphi < 1.5\%, 0 < \theta\theta < 90$,180<Re<780, 330<$Pr_{nf}$ <395. The comparison of the empirical upshot with anticipated Eq (4). is shown in Fig. 9. According to the [46, 47], the correlation is presented for high Prandtl number in developing region because the size of experimental facility is really large and spinning tube is obstacle. Although, classical equation should be expanded to estimate the empirical outcomes. The empirical data and square method was applied to determine the correlation in this research paper [43]. The peaked deflection of experimental data is relatively 19%. The inaccuracy of an equation can be acceptable to be used for estimating convective heat transfer in downward flow in slope tubes.

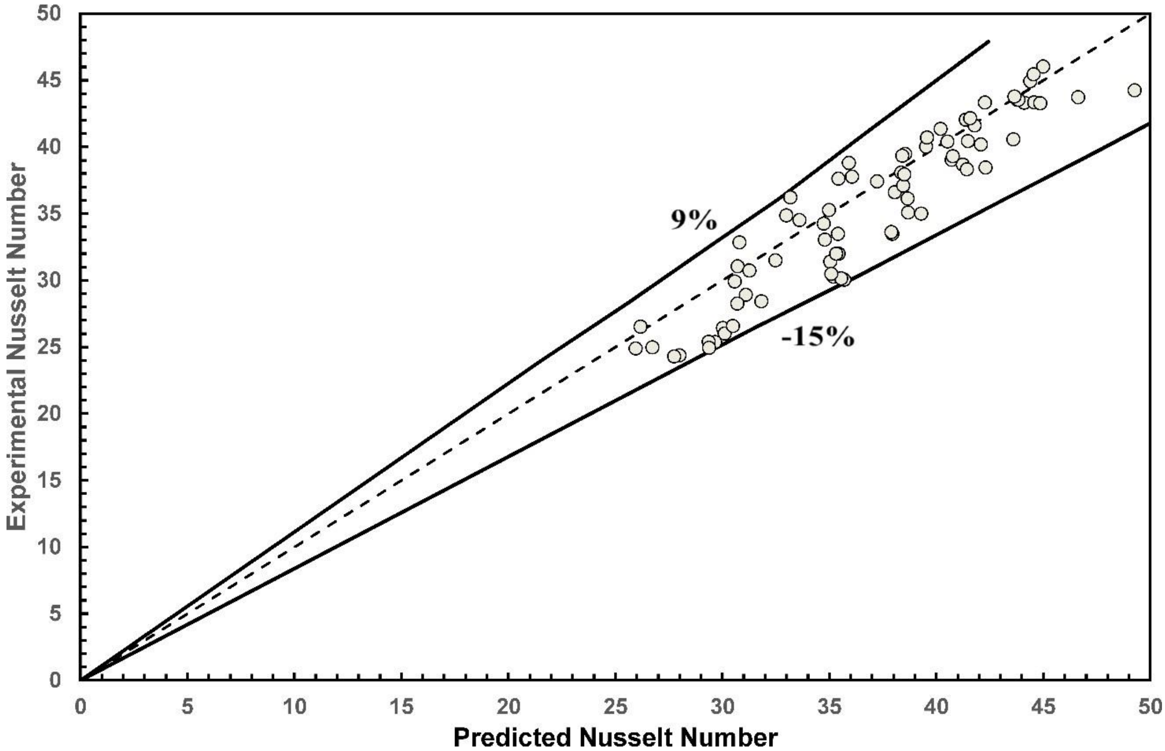

Figure 9. Constract of the empirical forced convective of the nanofluid flow with the estimation of Eq. (5)

Figure of merit (FOM)

The accompanying forced convection rise with a growth of pressure drop should be computed because of computing the effectiveness of simultaneous rise of forced convection and pumping power, the FOM might be acquired by means of [71,72]:

(3.5) $$FOM = \frac{h_{n_f}/h_{b_f}}{(\Omega_{n_f}/\Omega_{b\ f})^{(1/3)}}$$

The FOM is considered since it is able to understand that the use of nanofluid is beneficial or unbeneficial. Indeed, it help us to know that the nanofluid can be used to improve heat transfer while the pressure drop increase slightly. The FOM depicts the rate of rising forced convection with the rate of experimental pumping power. Accompanying nanofluid and negative slope can be employed for improving forced convection in a slope tube. If the FOM becomes more than the unit. Fig. 10 shows that using nanofluid is the reason which augments the forced convection to arrive 1.66%, which is observed in the weight mass fraction 1.5% and slope of -30. It is distinguished that changing the Darcy friction factor of nanofluid in downward flow in slope circular pipe is slight. This is due to the anti-friction features of copper oxide. The nanoparticle has an irregular shape, which acts as a roller between the heat exchanger walls and fluid. Accordingly, the friction decreases due to the replacement of the friction mode from the sliding mode to rolling mode. The roller impact was defined [73-76].

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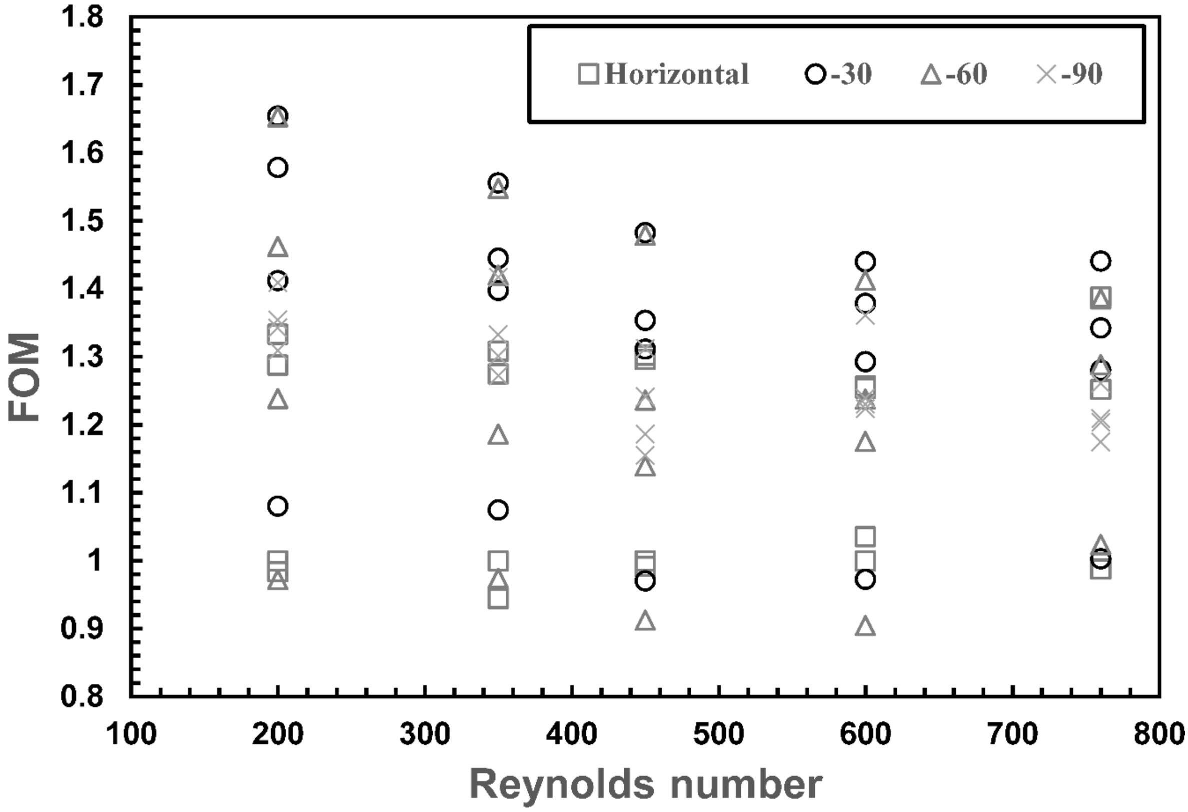

Figure 10. Constract of the empirical Nusselt number of the nanofluid flow with the estimation of Eq. (5)

CONCLUSION

The changing of forced convection and Darcy friction factor is studied with adding copper oxide-thermal oil nanofluid and downward flow in slope pipe. The range of weight concentration and inclination angle were applied from 0% to 1.5% and from 0 to -90, respectively. The results of research in downward single-phase flow demonstrates that the forced convection and Darcy friction factor rise 8% and 21% with a rise of the weight mass fraction of 0% to 1.5% as well as Reynolds number which varies from 180 to 780. A couple of new equations are defined in order to examine the alteration of forced convection and Darcy friction factor with boundary conditions such as isothermal wall tube and downward flow in oblique pips. The result of the equations is acceptable due to the peaked deviation from experimental results. The peaked aberration is lower than 19%. There is a reason why the rise of forced convection and Darcy friction factor is the diminution of the boundary layer, which is the augmentation of constant velocity and Brownian motion. This is because the adding nanoparticle and negative slope can increase the Darcy friction factor and forced convection. Thus, the accompanying forced convection improvement with a rise of pumping power is made. The result of accompaniment shows that most of the rate is more than unit, so it is advised to use negative inclination angle and nanofluid in industrial usages.

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