Heat Transfer Characteristics using TiO_2-Water Nano Fluid in Double Pipe Heat Exchanger

S.Manikandan
Assistant Professor
Department of Mechanical Engineering
Erode Sengunthar Engineering College Erode, Tamil Nadu 638 057
E-Mail : mechmani.mechanic@ gmail.com,

B.Govindharajan
Assistant Professor
Department of Mechanical Engineering
Erode Sengunthar Engineering College Erode, Tamil Nadu 638 057
E-Mail : nxman5@ gmail.com,

M.Ashok kumar
D.S.Balaji
(UG Students)

Department of Mechanical Engineering
Erode Sengunthar Engineering College Erode, Tamil Nadu 638 057

K.Balasubramaniam
A.Karthikeyan
(UG Students)

Department of Mechanical Engineering
Erode Sengunthar Engineering College Erode, Tamil Nadu 638 057

Abstract
Numerical investigation of heat transfer over a backward facing step using nanofluids is presented. Presently using Water and air only for heat transfer . In this heat transfer efficiently low output. Reason is basefluid not having relatively high density compare to nanofluid. In this chapter lot of research going on. IN this research TIO2 will be. e are trying to TIO2 nanofluid using investigate heat transfer rate. Nanoparticles having high thermal conductivity as TIO2 have better enhancement on heat transfer rate. The resonof choosing Tio2 having the thermal conductivity value is13.7w/mk.The use of twisted tape insert 5.5,6.0,6.5, will increase the swirl and turbulent flow and also increase the rate of heat transfer irrespective to velocity of fluid. In this research swirl flow and turbulent flow increase by using v-cut twisted tape.

Keywords: Nanofluid, heat transfer, thermal conductivity.

1. Introduction
Most of the researchers have concentrated much in the area of heat transfer enhancement in pipe flows. Many techniques and methods have been proposed and tested. One of the effective ways of achieving this is to introduce various types of inserts to increase the heat transfer area. Many types of plain tube configurations have been tested and the results presented in many papers. In addition, introduction of the swirl flow in tubes by implementing helical and spiral tube inserts has emerged as the latest method of improving the heat transfer characteristics. Many works have been done involving swirl flow generators.These swirl flow generators like helical and spiral tape inserts cause more turbulence in the flow of the fluid and thus decrease the boundary layer. Reduction in the boundary layer increases the heat transfer characteristics. Although heat transfer increases by the introduction of swirl flow generators, this also increases the pressure drop in the flow section which is a major disadvantage. Many researchers have concentrated on the methods to decrease the range of pressure drop due to swirl flow generators. Along with the use of swirl flow generators, application of nanofluids has also been utilized in this work. Use of nanofluids in the enhancement of heat transfer is very much effective and many researchers have already worked in this field.
Numerous methods have been employed to improve the heat transfer characteristics of basic heat transfer fluids like water, ethylene glycol, oil and many other heat transfer fluid mixtures. These fluids have comparatively low thermal conductivity values. Therefore, incorporation of micro and nano level particles would be an effective method in improving their thermal conductivity.Two working fluids namely water and CNT nanofluid are used. The reason behind the selection of CNT nanoparticles is that they have very large thermal conductivity values . The investigation of CNT particles to be used as enhancers in coolant is initiated due to its high thermal conductivity values.

The thermal conductivity values of CNT can be calculated by various means . Two concentrations (0.1% & 0.2%) of CNT based nanofluids are prepared with DI water as base fluid. Multi Walled Carbon Nano Tube (MWCNT) particles with surfactant are mixed in the DI water using an ultrasonic vibrator. To make the nanoparticles more stable and remain more dispersed in water, ultrasonic vibrator was used. Sonication was done for one hour continuously to obtain a more stable and evenly dispersed nanoparticle suspension. Initially Sodium dodecyl benzene sulfonate is used as a surfactant but it led to the problem of foam production. Then this problem can be avoided by using Gum Arabic as a surfactant. The TiO_2 Nano particles have an average size of 6 nm used for investigation in the present experimental work. The photographic view of the nanoparticles as seen by the naked eyes is shown in the Figure The distribution of TiO_2 nanoparticles at Nano scale can be observed under a Scanning electron Microscope.

The SEM images of TiO_2 nanoparticles as shown in the figure Preparation of nanofluids is an important stage and nanofluids are prepared in a systematic and careful manner. In this method a small amount of suitable surfactant, generally one tenth of mass of nanoparticles, is added to the base fluid and stirred continuously for few hours. In the present investigation, neither surfactants nor acid are added in the TiO_2 nanofluids, because with the addition of surfactants the thermo physical properties of nanofluids are affected . Addition of acid may damage the tube material because corrosion takes place after a few days with the prolonged usage of such nanofluids in practical applications . All the test samples of TiO_2 nanofluids used subsequently for estimation of their properties were subjected to magnetic stirring process followed by ultrasonic vibration for about 2 hours.It can be observed clearly from the graph that viscosity, density and thermal conductivity of the water increase with the addition of nanoparticles whereas the specific heat becomes relatively lower compared to that of water.

Table1.1 Physical properties of water

Sl.No	Physical Properties	Water
1	ρ (Kg/m3)	990
2	μ (Kg/ms)	0.0005494
3	κ (W/mK)	0.633
4	Cp (J/Kg. Pr	4182
5	(K)	3.56

2. Literature review

M.A. Ahmed[1] et al. laminar forced convection flow of Al_2O_3–waternanofluid in sinusoidal-wavy channel is numerically studied. The two-dimensional governing equations of continuity, momentum and energy equations in body-fitted coordinates are solved using finite volume method.

W.H. Azmi[2] et al.Nanofluids systems only used for increase the heat transfer. The enhancement in heat transfer coefficients in combination with structural modifications of flow systems namely, the addition of tape inserts. Experiments are undertaken to determine heat transfer coefficients and friction factor of TiO_2/water nanofluid up to 3.0% volume concentration at an average temperature of 30 C.

Ali Celen et al[3] investigation numerical model having two-dimensional equations was obtained by a CFD program and experimental data were evaluated for the verification procedure of the numerical data outputs. Hydrodynamics and thermal behaviors of the water–TiO_2 flow were calculated by constant heat flux and temperature-dependent settings.

M. Chandra Sekhara Reddy et al[4] investigated heat transfer, friction factor and thermal performance of three nanofluids different blends were prepared with ethylene glycol and water and TiO_2 nanoparticles and characterized for thermal conductivity as a function of temperature and volume concentration of nanoparticles. Based on the experimental results, it is observed that the thermal conductivity of TiO_2 nanofluids.

Chung-Kai Wang et al[5], conducted experimental investigations on Nanofluid TiO_2 nanoparticle-coated nickel wires were produced by electrical heating in various nanofluid concentrations ranging from 0.01 to 1 weight.Biling curves in all cases of coated nickel to the base fluid check heat transfer remarkably. Experimental results have been nanofluid convective heat transfer coefficient in turbulent regime.

H. Demir[6] et al conducted experimental investigations on forced convection flows of nanofluid consisting of water with TiO_2 and Al_2O_3 nanoparticles in a horizontal tube with constant wall temperature are investigated numerically. The horizontal test section is modeled and solved using a CFD program. Palm et al.'s correlations are used to determine the nanofluid properties.

GoutamSaha et al [7], investigated numerical analysisin horizontal circular pipe under turbulent flow conditionto understand the flow and heat transfer behavior of different nanofluids.TiO_2 nanoparticles are more environment-friendly and eco-friendly than the Al2O3 nanoparticles. The heat transfer performance is more influenced by the Brownian motion and size diameter of nanoparticles than the thermal conductivity of nanofluid.

Jaafar Albadr [8] et al. experimental study on the forced convective heat transfer and flow characteristics of a nanofluid consisting of water and different volume concentrations of Al2O3 nanofluid (0.3–2)% flowing in a horizontal shell and tube heat exchanger counter flow under turbulent flow conditions are investigated. The Al2O3 nanoparticles of about 30 nm diameter are used in the present study.

D. Madhesh et al [9], experimental investigate carried heat transfer potential and rheological characteristics of copper and titanium hybrid nanofluids using a tube in the counter flow heat exchanger. The nanofluids were prepared by dispersing the surface functionalized and crystalline copper and titania hybrid nanocomposite in the base fluid.

Mostafa Keshavarz Moraveji et al [10], CFD modeling of laminar forced convection on Al2O3 nanofluid with size particles equal to 33 nm and particle concentrations of 0.5, 1 and 6 wt.% Three-dimensional steady-state governing partial differential equations was discretized using finite volume method. Influences of some important parameters such as nanoparticle concentration and Reynolds number on the enhancement of nanofluid heat transfer have been investigated.

P. Murugesan et al [11], investigated heat transfer, friction factor and thermal performance factor characteristics of circular tube fitted with plain twisted tape and V-cut twisted tape for twist ratios 2.0, 4.4 and 6.0.The V-cut twisted tape offered a higher heat transfer rate, friction factor and also thermal performance factor compared to the plain twisted tape in all Reynolds number.

Omid Mahian et al [12].In this performed for the flow and heat transfer of TiO2/water nanofluid. . The investigations are undertaken in the Reynolds number range of 9000-28,000 for flow in tubes and with tapes of different twist ratios. The simplified equations are solved analytically to obtain expressions for the velocity, temperature, and entropy generation distributions. The results are presented for different values of nanofluid volume fractions. To calculate the thermal conductivity and viscosity of TiO2/water nanofluid.

S.Rohit et al [13]. thermal conductivity and viscosity of Fe3O4 nanoparticle in paraffin were investigated up to a volume fraction range of 0.01 0.1 of nanoparticle. The mean diameter of Fe3O4 nanoparticle was 25 nm. The thermal conductivity of nanofluids has been measured using the transient hot-wire method based. The experimental results showed that the thermal conductivity increases with an increase of particle volume fraction.

Z. Said et al [14].It is an using for temperature, pressure drop, pumping power, zeta potential, size and densities were analyzed for fresh prepared samples as well as for samples used in a flat plate solar collector . The thermal conductivity enhancement of the two nanofluids demonstrated a nonlinear relationship with respect to temperature and volume fraction. Al2O3/water and TiO2/water-based nanofluids, has raised serious concerns about the use of nanofluids for heat transfer enhancement.

Smith Eiamsa-ard et al [15].In this work is to enhance thermal performance characteristics in a heat exchanger tube multiple twisted tapes in different arrangements and TiO2 nanoparticles with different concentrations as the working fluid. The tube inserted the multiple twisted tapes showed superior the+rmal performance factor when compared with plain tube or the tube inserted a single twisted tape, due to continuous multiple swirling flow and multi-longitudinal vortices flow along the test tube.

A.R. Sajadi et al [16].Turbulent heat transfer behavior of titanium dioxide/water nanofluid in a circular pipe was investigated experimentally where the volume fraction of nanoparticles. Experimental results have been compared with the existing correlations for nanofluid convective heat transfer coefficient in turbulent regime.

Thaklaew Yiamsawas et al [17],Experimental investigations are performed to find out the viscosity of TiO2 and Al2O3 nanoparticles mixture with ethylene glycol and water. The experiments are conducted with various volume fractions. Using the experimental data, a useful correlation is presented to predict the viscosity. The use of nanofluid enhances heat transfer coefficient with no significant enhancement in pressure drop compared to water.

Weerapun Duangthongsuk et al [18].conducted experimental investigations on Nanofluid is a new class of heat transfer fluids engineered by dispersing metallic or non-metallic nanoparticles. Their use remarkably augments the heat transfer potential of the base liquids. Heat transfer coefficient and friction factor of the TiO2-water nanofluids flowing in a horizontal double tube counter- flow heat exchanger under turbulent flow conditions, experimentally.

3. Methodology

Specifications of Heat Exchanger Used

Inner pipe ID = 12mm
Inner pipe OD=15mm
Outer pipe ID =34mm
Outer pipe OD =38mm
Material of construction= Copper
Heat transfer length= 1.5m

Table 3.1 Twist ratio of strip inserts

Strip	Twist ratio yw
1	5.5
2	6.0
3	6.5

The present work deals with finding the friction factor and the heat transfer coefficient for the various types of twisted tapes with twist ratios (yw=5.5, 6.0, 6.5)and finally finding the heat transfer enhancement by using nanofluid.

4. Experimental setup

The schematic diagram of the experimental setup is shown in Figure 1. The experimental set up consists of a pump, heat exchanger, test section, calming section, and a fluid reservoir. A plastic container of 7 litre capacity is used as the fluid reservoir. Test and calming sections are made of straight copper tube with the dimensions of 1000 mm long, 10 mm ID and 12 mm OD. Uniform heating is provided by ceramic beads coated electrical SWG Nichrome heating wire of resistance 120 Ω wound on the test section. A thick insulation is provided over the electrical winding using glass wool to minimize heat loss. The terminals of the Nichrome wire are attached to an auto-transformer, by which heat flux can be varied by varying the voltage. The fluid and wall temperatures are measured by using calibrated RTDs and the output can be noted using the digital display units.

A differential U-tube manometer is fitted across the test section to measure the pressure drop. The fluid after passing through the heated test section flows through a riser section and then through the cooling unit which is an air cooled heat exchanger and finally it is collected in the reservoir. A centrifugal pump is used to circulate the fluid through the circuit. The flow rate of the fluid is varied using two rota meter of rating 0.1 – 1 lph and 50 – 1500 lph for laminar and turbulent flows respectively. The present experimental work uses three helical screw tape inserts with twist ratios of 1.78, 2.44, and 3 with spacers.

Double pipe heat Exchanger

Double pipe heat exchangers are the simplest exchangers used in industries. On one hand, these heat exchangers are cheap for both design and maintenance, making them a good choice for small industries. But on the other hand, low efficiency of them beside high space occupied for such exchangers in large scales, has led modern industries to use more efficient heat exchanger like shell and tube or other ones. But yet, since double pipe heat exchangers are simple, they are used to teach heat exchanger design basic to students and as the basic rules for modern and normal heat exchangers are the same, students can understand the design techniques much easier. But yet, since double pipe heat exchangers are simple, they are used to teach heat exchanger design basic to students and as the basic rules for modern and normal heat exchangers are the same, students can understand the design techniques much easier. To start the design of a double pipe heat exchanger, the first step is to calculate the heat duty of the heat exchanger.

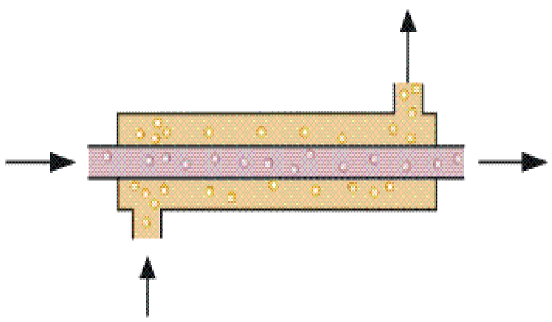


Fig 4.1. Test Section

Twist-tape inserts:

The tape twisted in the form of screw-tape with similar geometry of the helical tape is a modified form of the twisted-tape wounded on a core-rod. The both helical screw-tape and the twisted-tape generate a similar swirling flow in the circular tube and both of them possess different characteristics of flow. For the helical screw-tape, the swirling flow rotates in single way smooth direction of flow like a screw motion, while the twisted-tape shows the swirling flow in two way directions of parallel flows simultaneously. Because of lower pressure drop and ease of manufacturing, the twisted-tape is, in general, more popular than the helical screw-tape having a higher heat transfer rate at the same mass flow rate. In a heat recovery System, the helical screw-tape can be well applied due to low Reynolds number in the system. This helical screw tape can help to promote higher heat transfer exchange rate than the use of twisted-tape because of shorter pitch length which leads to stronger swirling flow and longer residence time in the tube.Heat transfer in a concentric double tube heat exchanger fitted with tight-fit, regularly spaced and fulllength helical screw-tape swirl generators and found that the full-length helical tape with core-rod yields the maximum heat transfer rate at about 10% better than that without corerod but considerably higher friction loss.

Fig 4.1 Twisted-tape inserts.

5. CFD Analysis

Meshing is the discretization of the domain into small volumes where the equations are solved by the help of iterative methods. Modeling The tape twisted in the form of screw-tape with similar geometry of the helical tape is a modified form of the twisted-tape wounded on a core-rod. The both helical screw-tape and the twisted-tape generate a similar swirling flow in the circular tube and both of them possess different characteristics of flow. For the helical screw-tape, the swirling flow rotates in single way smooth direction of flow like a screw motion, while the twisted-tape shows the swirling flow in two way directions of parallel flows simultaneously.

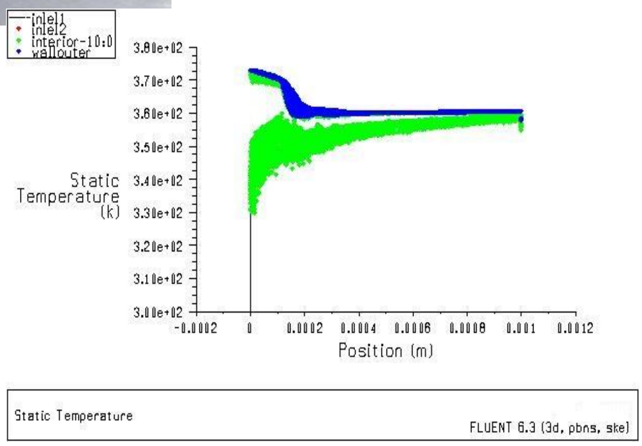
Heat exchanger is built in the GAMBIT 3.2.16 design. It is a parallel-flow heat exchanger. In the operation tool bar geometry is selected with positive-z. The IGES file is imported. Out of 3 planes, viz, XY-plane, YZ-plane and ZX-plane, the YZ-plane is selected for the first sketch. A 1000mm length and 6 mm radius cylinder is created using volume command and insert volume v1 is subtracted form volume v2. And volume v3 of 950 mm length and thickness 4mm is created and moved 50 mm in z-axis.

Table 5.1 Part classification.

Part number:	Part of The model	State type
1	Inner fluid	Fluid
2	Inner pipe	Solid
3	Outer fluid	Fluid
4	Outer pipe	Solid

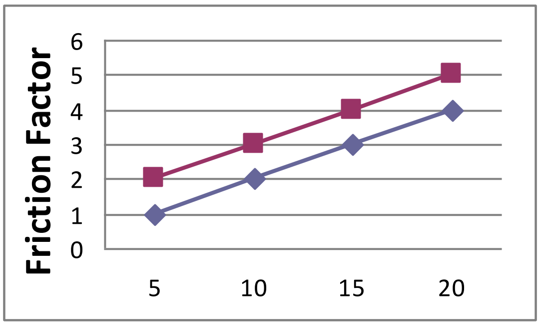
Boundary Conditions:

Boundary conditions are used according to the need of the model. The inlet and outlet conditions are defined as velocity inlet and pressure outlet. As this is a counter-flow with two tubes so there are two inlets and two outlets. The walls are separately specified with respective boundary conditions. No slip condition is considered for each wall. Except the tube walls each wall is set to zero heat flux.



6. Result and Discussion

The plots give an idea of flow separation at several parts of the heat exchanger



Reynolds number

Fig 6.1 Parallel flow(a) f & Re

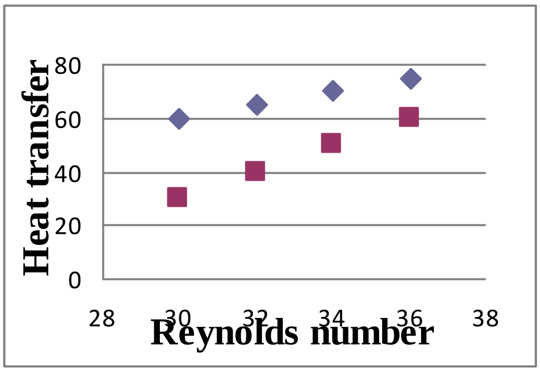


Fig 6.2

Twist ratio.6.0 Counter flow

Different group of workstation and assigned operation as shown in fig

7. Conclusion

An experimental study performed in order to investigate the effect of nanoparticle volume fraction of TiO2–water nanofluion the heat transfer characteristic and pressure drop in a wide range of nanoparticle volume fraction and Reynolds number in turbulent flow. It is observed that by increasing the Reynolds number or nanoparticle volume fraction, the Nusselt number increases. Mean while all nanofluids have a higher Nusselt number compared to distilled water. By use the nanofluid at high Reynolds number more power compared to low Reynolds number needed to compensate the pressure drop of nanofluid, while increments in the Nusselt number for all Reynolds numbers are approximately equal.

8. References

M.A.Ahmed , M.Z.Yusoff, K.C.N,N.H.Shuaib. "The effectsofwavy-wallphaseshiftonthermal-hydraulic performanceofAl2O3–waternanofluidflow in sinusoidal-wavychannel". Case StudiesinThermalEngineering4(2.014)153–165.

W.H. Azmi ,K.V. Sharma , P.K. Sarma c, Rizalman Mamat , Shahrani Anuar. " Comparison of convective heat transfer coefficient and friction factor of TiO2 nanofluid flow in a tube with twisted tape inserts". International Journal of Thermal Sciences 81 (2014) 84e93.

Ali Celen , Nurullah Kayaci , Alican Çebi , Hakan Demir , Ahmet Selim Dalkılıç , Somchai Wongwises. " Numerical investigation for the calculation of TiO2-water nanofluids' pressure drop in plain and enhanced pipes". International Communications in Heat and Mass Transfer 53 (2014) 98–108.

M. Chandra Sekhara Reddy, VeeredhiVasudevaRao. "Experimental investigation of heat transfer coefficient and friction factor of ethylene glycol water based TiO2 nanofluid in double pipe heat exchanger with and without helical coil inserts", International Communications in Heat and Mass Transfer 50, (2014)68–76.

Chen-Kang Huang , Chih-Wei Lee, Chung-Kai Wang. "Boiling enhancement by TiO2 nanoparticle deposition". International Journal of Heat and Mass Transfer 54 (2011) 4895–4903.

H. Demir, A.S. Dalkilic a, N.A. Kürekci a, W. Duangthongsuk b, S. Wongwises. " Numerical investigation on the single phase forced convection heat transfer characteristics of TiO2 nanofluids in a double-tube counter flow heat exchanger". International Communications in Heat and Mass Transfer 38 (2011) 218–228.
GoutamSaha, Manosh C. Paul. "Numerical analysis of the heat transfer behaviour of water based Al2O3 and TiO2 nanofluids in a circular pipe under the turbulent flow condition", International Communications in Heat and Mass Transfer 56 (2014) 96–108.

Jaafar Albadr , Satinder Tayal , Mushtaq Alasadi. " Heat transfer through heat exchanger using Al2O3 nanofluids at different concentrations". Case Studies in Thermal Engineering 1 (2013) 38–44.
.
D. Madhesh ,R. Parameshwaran, S. Kalaiselvam. "Experimental investigation on convective heat transfer and rheological characteristics of Cu–TiO2 hybrid nanofluids". Experimental Thermal and Fluid Science 52 (2014) 104–115.

Mostafa Keshavarz Moraveji , Reza Mohammadi Ardehali. "CFD modeling (comparing single and two-phase approaches) on thermal performance of Al2o3/water nanofluid in mini-channel heat sink". International Communications in Heat and Mass Transfer 44 (2013) 157–164.

P. Murugesan, K. Mayilsamy, S. Suresh, P.S.S. Srinivasan. "Heat transfer and pressure drop characteristics in a circular tube fitted with and without V-cut twisted tape insert". International Communications in Heat and Mass Transfer 38 (2011) 329–334.

Omid Mahian , Ioan Pop ,Ahmet Z, Sahin , Hakan F. Oztop , Somchai Wongwises. "Irreversibility analysis of a vertical annulus using TiO2/water nanofluid with MHD flow effects". International Journal of Heat and Mass Transfer 64 (2013) 671–679. (2014) 65–76.

S.Rohit ,S. Khedkara, Sai Kiran.A,Shriram S. Sonawanea , Kailas . Wasewara, Suresh.S Umreb. "Thermo physical characterization of Paraffin based Fe3O4 nanofluids". Procedia Engineering 51 (2013) 342 – 346.

Z. Said, , R. Saidur , A.Hepbasli , N.A. Rahim. " New thermophysical properties of water based TiO2 nanofluid—The hysteresis phenomenon revisited". International Communications in Heat and Mass Transfer 58 (2014) 85–95.

Smith Eiamsa-ard ,Kunlanan Kiatkittipong. " Heat transfer enhancement by multiple twisted tape inserts and TiO2/water nanofluids". Applied Thermal Engineering 70 (2014) 896e924.

A.R. Sajadi,M.H. Kazemi ,. "Investigation of turbulent convective heat transfer and pressure drop of TiO2/water nanofluid in circular tube".International Communications in Heat and Mass Transfer 38 (2011) 1474–1478.

Thaklaew Yiamsawas , Omid Mahian, Ahmet Selim Dalkilic,Suthep Kaewnai, Somchai Wongwises. "Experimental studies on the viscosity of TiO2 and Al2O3 nanoparticles suspended in a mixture of ethylene glycol and water for high temperature applications" , Applied Energy 111 (2013) 40–45.

Weerapun Duangthongsuk, Somchai Wongwises. " An experimental study on the heat transfer performance and pressure drop of TiO2-water nanofluids flowing under a turbulent flow regime". International Journal of Heat and Mass Transfer 53 (2010) 334–344.