14-15 March 2019
St Cross College, University of Oxford, UK.

A perspective on new nanoparticle enhanced heat transfer fluids and their applications in solar energy systems

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Acknowledgement
This research was possible due to cooperation under COST European Network Nanouptake, CA 15119, which is dedicated to overcome the barriers in implementing nanoparticle enhanced fluids in energy area.

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- **Research objective**: to investigate the recent advances in the nanofluids' applications in solar energy systems by means of experimental and numerical work.

- **Research start point:** manufacture of three single component nanofluids and two hybrid nanofluids followed by a deep experimental study of their thermophysical properties and stability.

- **Performed work:** all the experimental results were introduced in a numerical analysis to outline the advantages of the new nanoparticle enhanced fluid on a solar collector efficiency if compared to conventional heat transfer fluids.

- **Overall conclusion:** it may strongly affirm that the heat transfer performance in a tube is enlarged by suspension of hybrid nanoparticles if compared with that of pure water.

- This research was possible due to **efficient cooperation under COST European Network Nanouptake**, which is dedicated to overcome the barriers in implementing nanoparticle enhanced fluids in solar energy area and to increase their technology readiness level from existing TRL 3-4 to validation in the relevant environment (TRL 5).

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STATE OF THE ART

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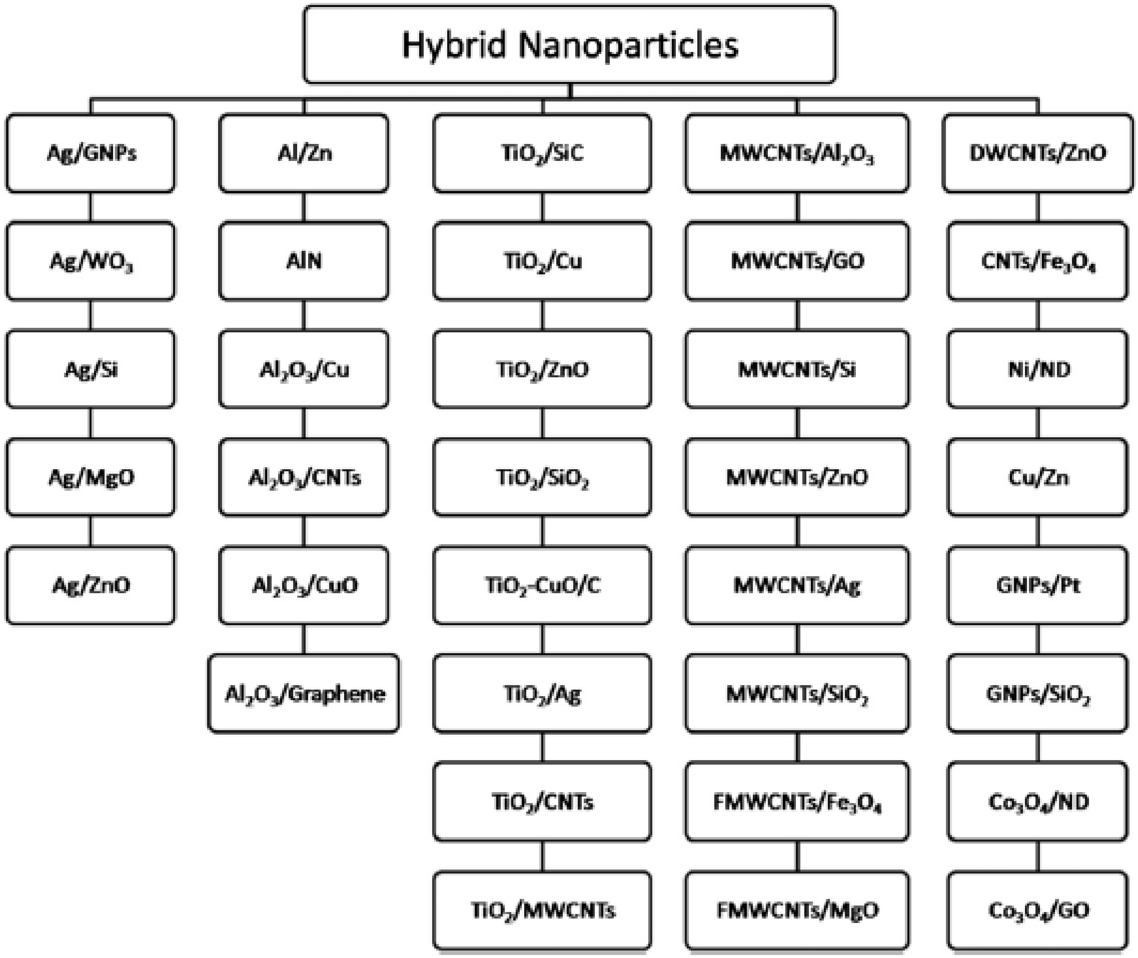
- A **new heat transfer fluid** can be engineered with the help of modern nanotechnology that can produce different nanoparticles (metallic/nonmetallic, carbon or silicon based).

- Nanomaterials, with unique thermal properties, can be added in certain conditions to basic fluids in order to improve their characteristics. Thus, **nanoparticle enhanced fluids (nanofluids)** were firstly developed by suspending nanoparticles in traditional heat transfer fluids such as water, oil, and ethylene glycol or even ionic liquids. Studies in this field indicate that **exploiting nanofluid in solar systems offers unique advantages** over conventional fluids.

- If one can obtain an enhancement in the heat transfer rate in industrial applications then there will be noticeable increase in energy savings and decrease in processing time. In this idea, as a new research direction, nanofluids were proposed as new heat transfer fluids for many years. However, **new research trend in the area of nanofluids goes to exploration of other types of nanoparticles and new fluids named hybrid nanofluids.** These new heat transfer fluids are engineered by adding complex nanoparticles (hybrid ones) or by mixing two different nanofluids and an intense work in this direction was noticed in the literature.


Hybrid Nanoparticles
Ag/GNPs
Ag/WO_3
Ag/Si
Ag/MgO
Ag/ZnO
Al/Zn
AlN
Al_2O_3/Cu
Al_2O_3/CNTs
Al_2O_3/CuO
Al_2O_3/Graphene
TiO_2/SiC
TiO_2/Cu
TiO_2/ZnO
TiO_2/SiO_2
TiO_2-CuO/C
TiO_2/Ag
TiO_2/CNTs
TiO_2/MWCNTs
MWCNTs/Al_2O_3
MWCNTs/GO
MWCNTs/Si
MWCNTs/ZnO
MWCNTs/Ag
MWCNTs/SiO_2
FMWCNTs/Fe_3O_4
FMWCNTs/MgO
DWCNTs/ZnO
CNTs/Fe_3O_4
Ni/ND
Cu/Zn
GNPs/Pt
GNPs/SiO_2
Co_3O_4/ND
Co_3O_4/GO

Hybrid nanofluid	Preparation	Observation	Reference
Ag - Al_2O_3/ water	2 nanofluids mixed	hybrid nanofluids were effective if compared with mono nanofluids	Han and Rhi [11]
Al_2O_3–Cu / water	2 particles mixed in water	improvement of 13.56% in Nu at Re=1730	Momim [12]
Cu-TiO_2 / water	hybrid nanocomposite	Nu increases with 52%, 49% and 68% respectively	Madhesh and Kalaiselvam [13]
Al_2O_3–Cu / water	hybrid nanocomposite	enhancement of 13.56% in Nu at Re=1730	Suresh et al. [14]
γ-Al_2O_3 – MWNT / water	hybrid nanocomposite	augmentation of the thermal conductivity up to 14.75%	Abbasi et al. [16]
Ag - MWNT/ water	hybrid nanocomposite	Ag/MWNT hybrid nanofluids have 14.5% upper thermal conductivity than that of the MWNT nanofluid	Munkhbayar et al. [17]
Cu / Cu_2O –water	hybrid nanocomposite	Thermal conductivity enhancement	Nine et al. [18]
MWCNT - Fe_2O_3 / water	2 nanoparticles in water	28% augmentation in thermal conductivity	Chen et al. [19]
MWCNT–Fe_3O_4/water	hybrid nanocomposite	31.10% augmentation in Nu at Re=22000	Sundar et al [20]
Fe_3O_4+SiO_2 – MWNT / water	hybrid nanocomposite	thermal conductivity augmentation of 24.5% for 0.03% vol	Baby and Ramaprabhu [21]
Al_2O_3 + Ag/ Water	2 nanoparticles mixed in water	the hybrid (0.6vol.%Al_2O_3 + 2.4vol.%Ag) nanofluid enhances the heat transfer coefficient by 126%–148% than that of pure water.	Nimmagadda and Venkatasubbaiah [22]
Ag+MgO / water	hybrid nanocomposite	thermal conductivity and viscosity of hybrid increase with hybrid fraction	Esfe et al. [23]

EXPERIMENTAL

- Three types of oxide nanoparticles aqueous solution were used for this investigation: Al_2O_3 (nanoDur) nanoparticles (43 nm) in 50.70 % wt. aqueous solution, TiO_2 (30nm) in 34.03 % wt. aqueous solution and SiO_2 (20nm) in 40% wt. aqueous solution.
- Dispersions were from Alfa Aesar Germany and the base fluid was distilled water.
- The suspensions were subjected to 60 minutes ultrasonic vibration.

Nanofluid type	Base fluid	Volume fraction of nanoparticles, φ, %vol.
Alumina nanofluids	water	1.00 % vol. Al_2O_3
	water	1.50 % vol. Al_2O_3
	water	2.00 % vol. Al_2O_3
	water	3.00 % vol.Al_2O_3
Silica nanofluids	water	1.00 % vol.SiO_2
	water	1.50 % vol.SiO_2
	water	2.00 % vol.SiO_2
	water	3.00 % vol.SiO_2
Titania nanofluids	water	1.00 % vol.TiO_2
	water	1.50 % vol.TiO_2
	water	2.00 % vol.TiO_2
	water	3.00 % vol.TiO_2
Hybrid nanofluids	water	0.50 % vol.Al_2O_3 + 0.50 % vol. SiO_2
	water	0.50 % vol.Al_2O_3 + 1.00 % vol.SiO_2
	water	0.50 % vol.Al_2O_3+ 1.50 % vol. SiO_2
	water	0.50 % vol.Al_2O_3+ 2.50 % vol. SiO_2
	water	0.50 % vol.Al_2O_3 + 0.50 % vol. TiO_2
	water	0.50 % vol.Al_2O_3 + 1.00 % vol.TiO_2
	water	0.50 % vol.Al_2O_3+ 1.50 % vol. TiO_2
	water	0.50 % vol.Al_2O_3+ 2.50 % vol. TiO_2

Nanofluid type and volume concentration	Zeta potential, mV	Remarks
1.00 % vol. Al_2O_3	+19.20	relatively stable
1.50 % vol. Al_2O_3	+27.00	stable
2.00 % vol. Al_2O_3	+27.90	stable
3.00 % vol.Al_2O_3	+25.22	stable
1.00 % vol.SiO_2	-37.14	very stable
1.50 % vol.SiO_2	-42.09	very stable
2.00 % vol.SiO_2	-38.33	very stable
3.00 % vol.SiO_2	-45.82	very stable
1.00 % vol.TiO_2	-24.27	relatively stable
1.50 % vol.TiO_2	-26.85	stable
2.00 % vol.TiO_2	-31.46	very stable
3.00 % vol.TiO_2	-33.38	very stable
0.50 % vol.Al_2O_3 + 0.50 % vol. SiO_2	-26.11	stable
0.50 % vol.Al_2O_3 + 1.00 % vol.SiO_2	-34.53	very stable
0.50 % vol.Al_2O_3+ 1.50 % vol. SiO_2	-32.90	very stable
0.50 % vol.Al_2O_3+ 2.50 % vol. SiO_2	-39.54	very stable
0.50 % vol.Al_2O_3 + 0.50 % vol. TiO_2	-30.47	very stable
0.50 % vol.Al_2O_3 + 1.00 % vol.TiO_2	-23.76	relatively stable
0.50 % vol.Al_2O_3+ 1.50 % vol. TiO_2	-25.91	stable
0.50 % vol.Al_2O_3+ 2.50 % vol. TiO_2	-30.47	very stable

Specific heat

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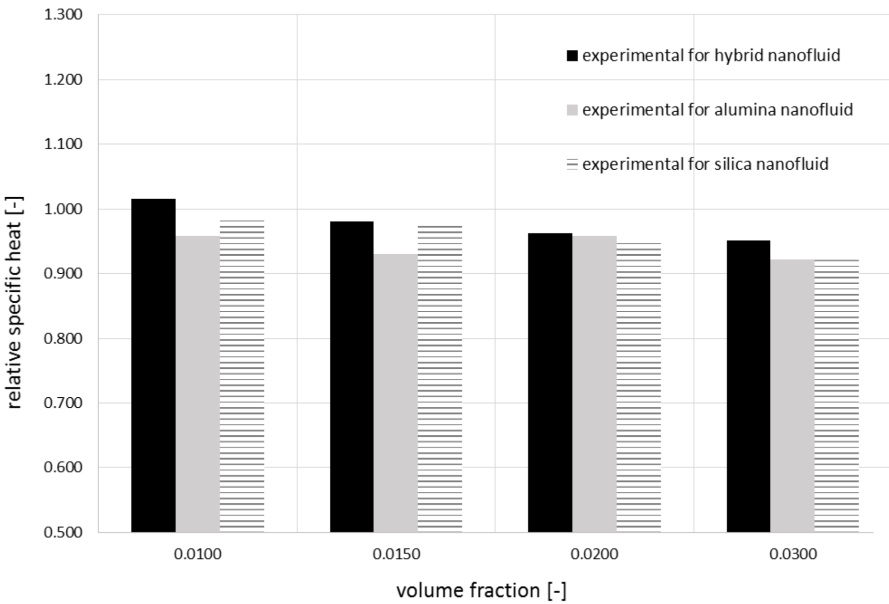
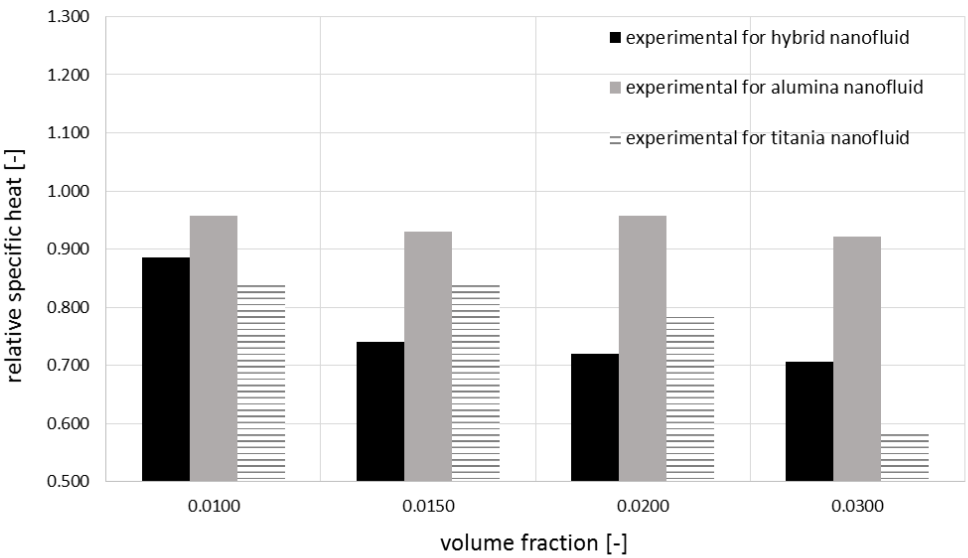


Specific heat measurements were made at room temperature using a DSC equipment from Mettler-Toledo, using aluminum capsules of 40 μl and all the probes had 4-6 mg.



The measurement precision is 1%, having a cooling system type RCS40.

For each determination three tests were performed and the average value was considered for interpretation.

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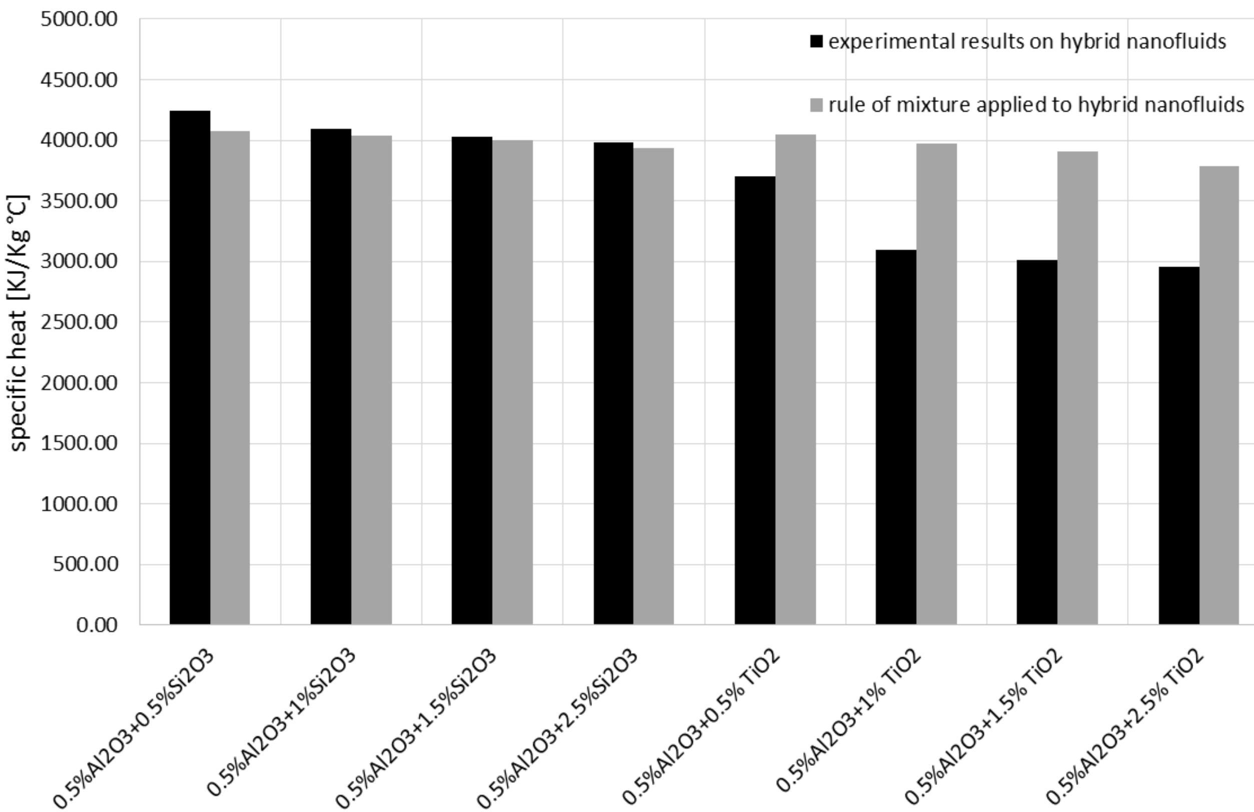
experimental results on hybrid nanofluids
rule of mixture applied to hybrid nanofluids
specific heat [KJ/Kg °C]
5000.00
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
0.5%Al2O3+0.5%Si2O3
0.5%Al2O3+1%Si2O3
0.5%Al2O3+1.5%Si2O3
0.5%Al2O3+2.5%Si2O3
0.5%Al2O3+0.5% TiO2
0.5%Al2O3+1% TiO2
0.5%Al2O3+1.5% TiO2
0.5%Al2O3+2.5% TiO2

Viscosity

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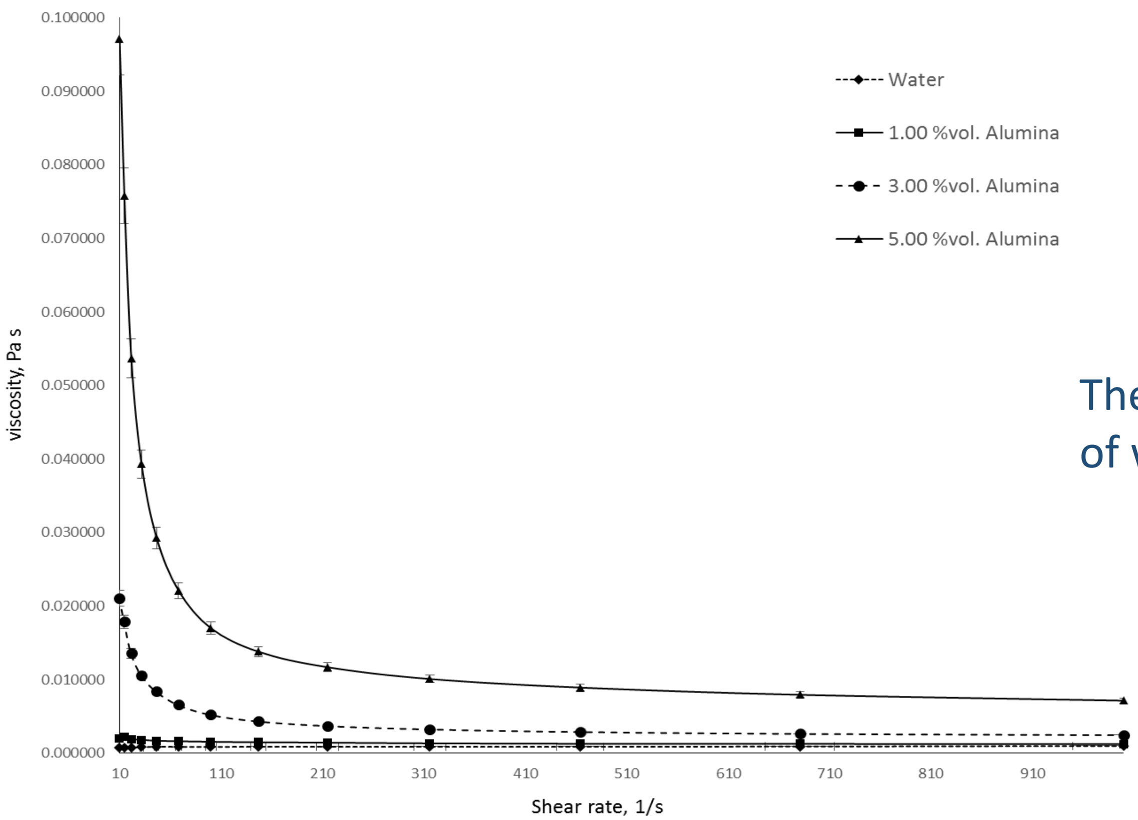
Viscosity measurements were carried out both at room temperature (25°C) and with temperature variation. Rheological characteristics of nanofluids were measured using a modular rheometer (Physica MCR 501, Anton Paar) with a Peltier system for temperature control.



The viscosity variation with shear rate of water and alumina nanofluids

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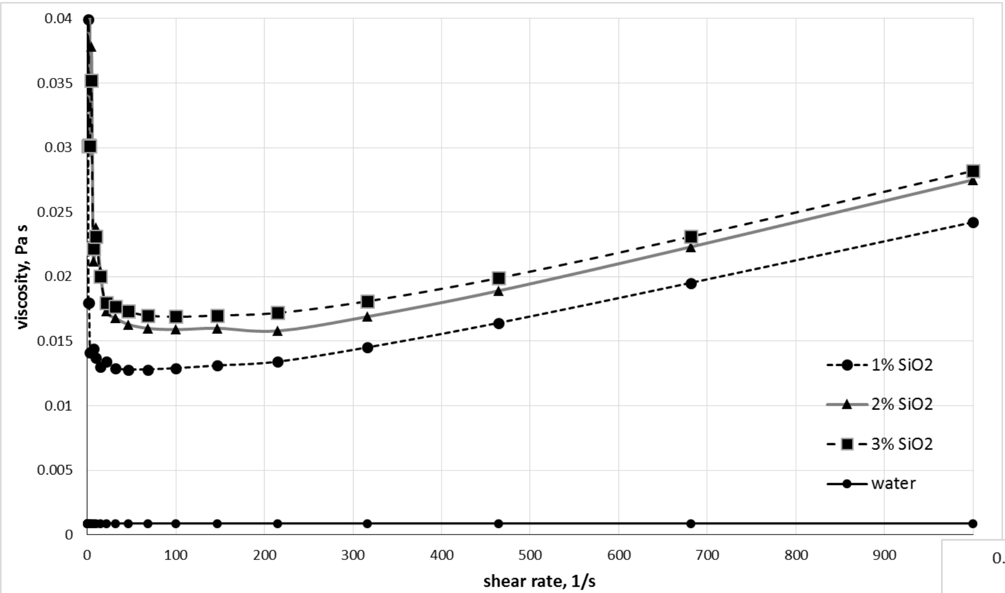
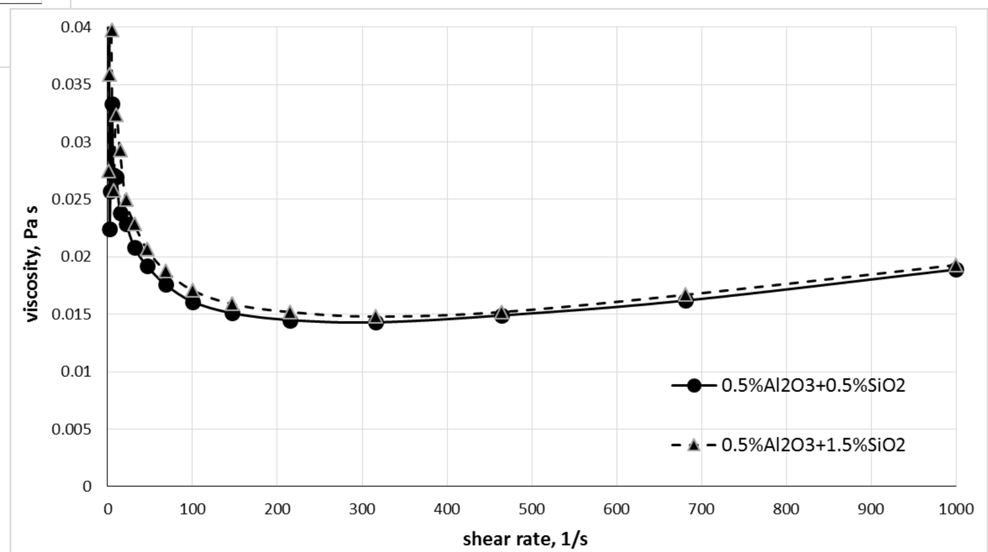


The viscosity variation with shear rate for:

- Silica nanofluids
- Alumina + silica hybrid nanofluids



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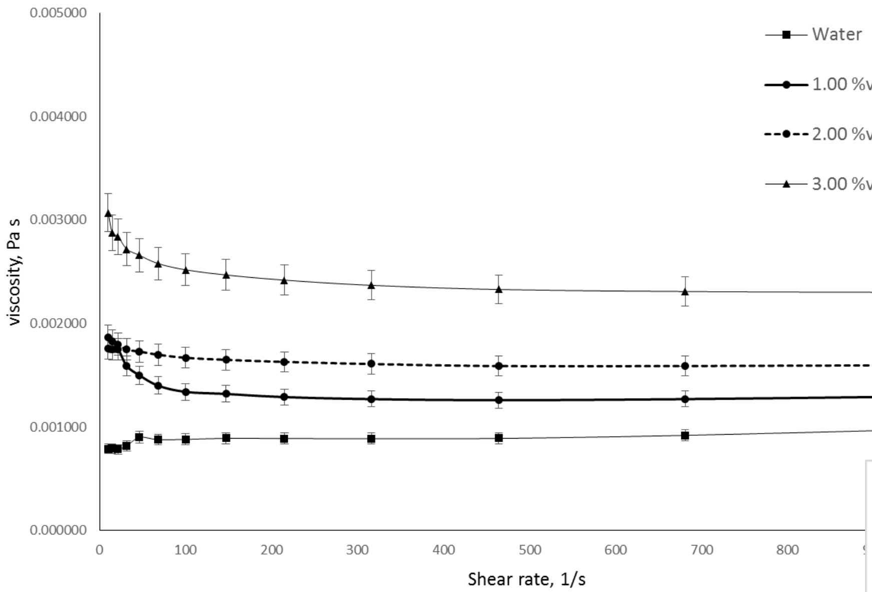
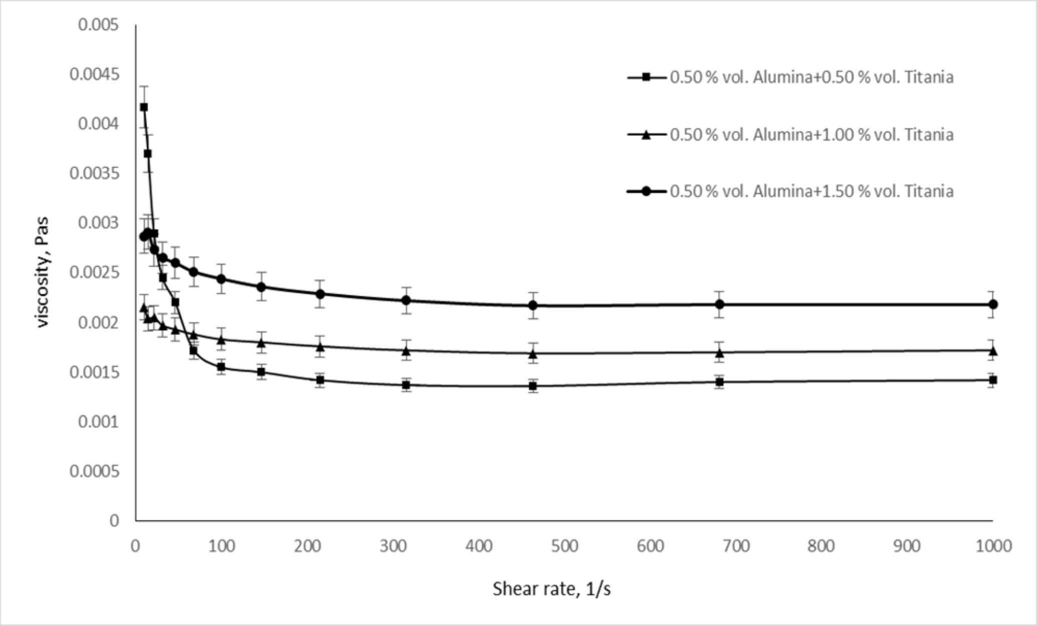


The viscosity variation with shear rate for:

- Titania nanofluids
- Alumina + titania hybrid nanofluids



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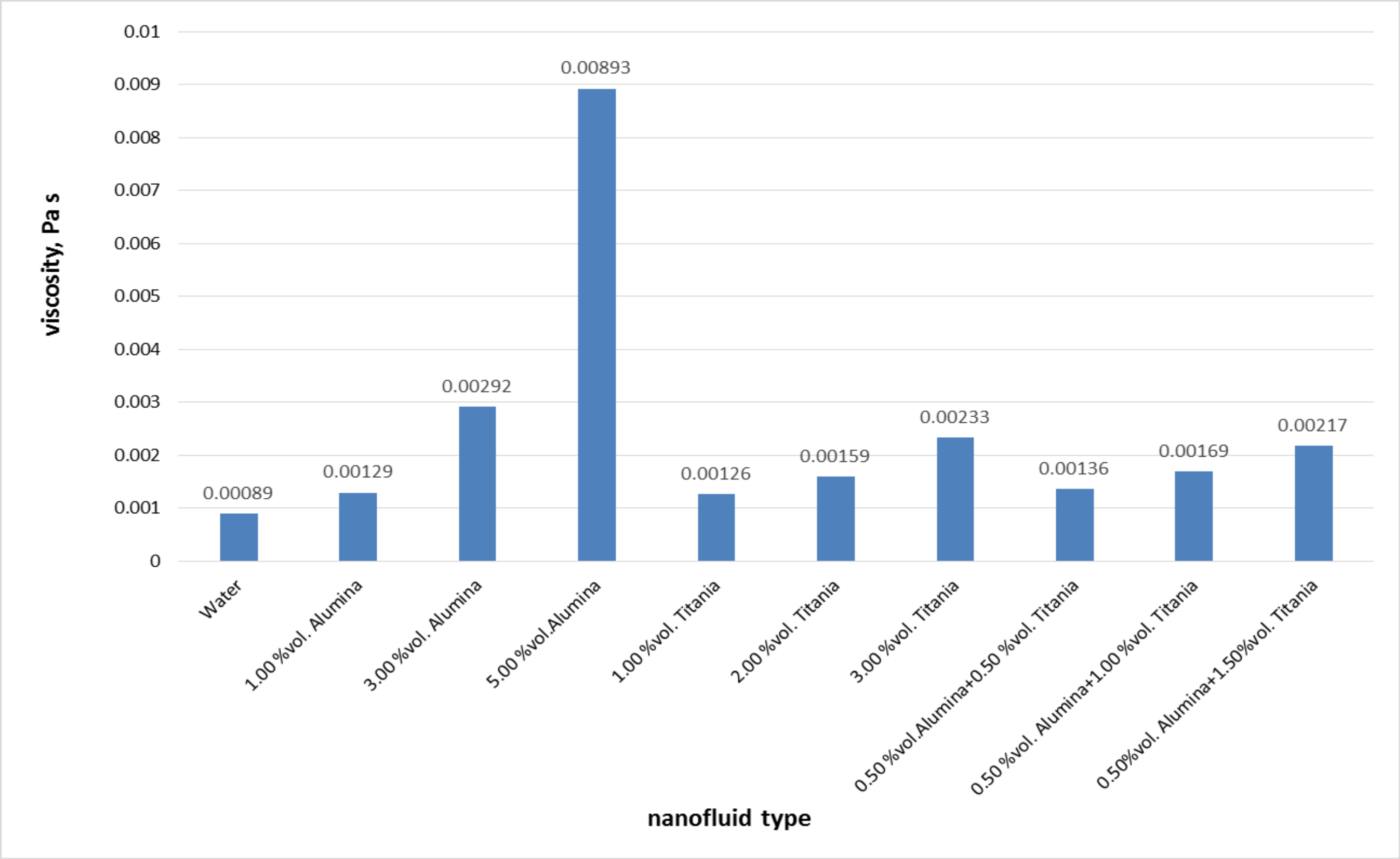

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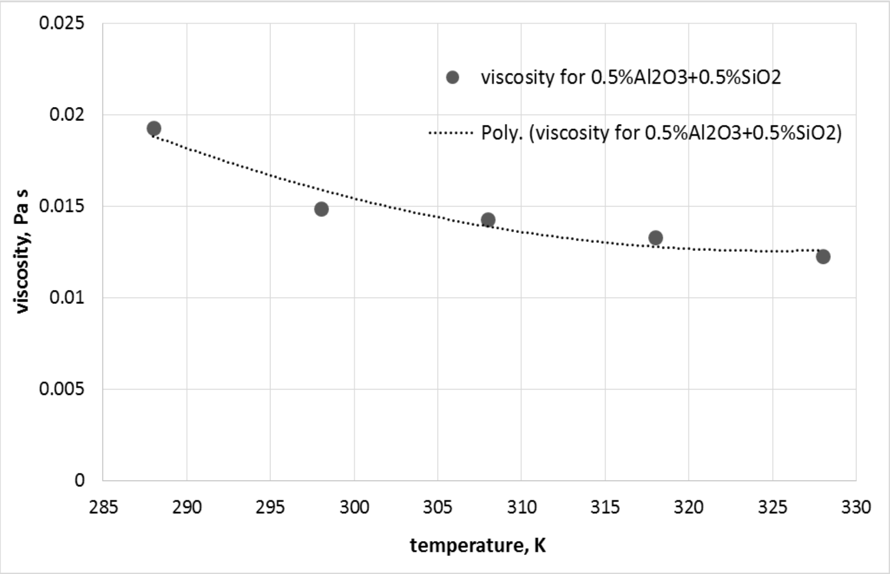
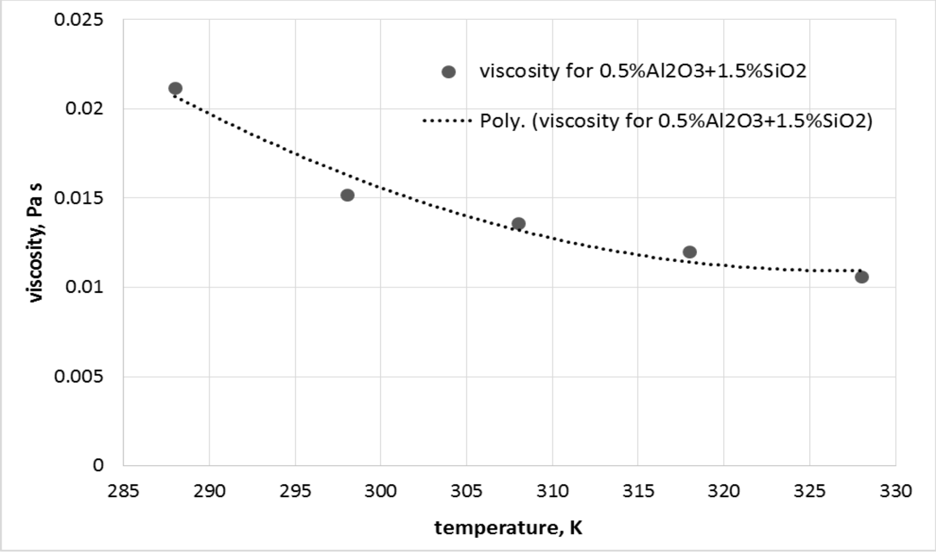


The viscosity variation with temperature for alumina + silica hybrid nanofluids



Thermal conductivity

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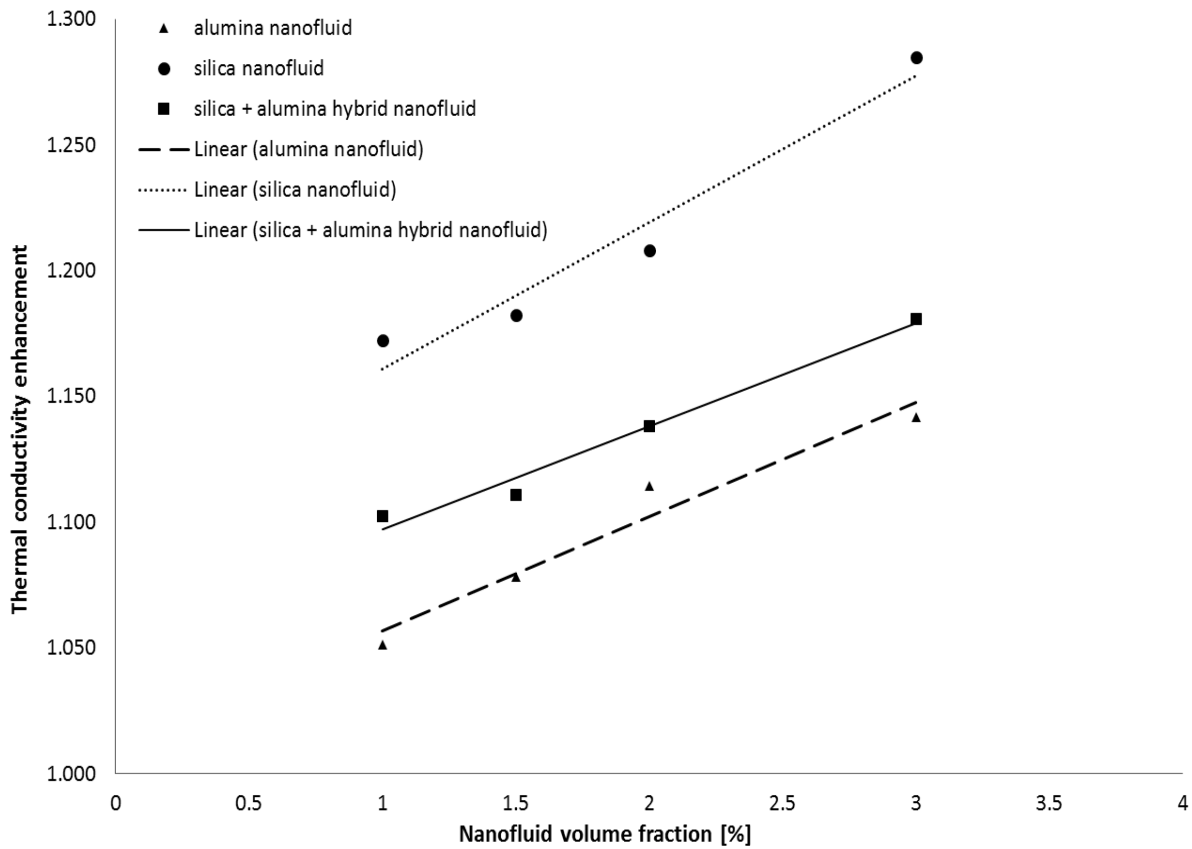
Thermal conductivity measurements were carried out both at the **room temperature (25°C) and with temperature variation between 20-50°C** with a KD 2 Pro Thermal Properties Analyzer (Decagon Devices, USA). The KD2 was calibrated by using glycerol and distilled water at the room temperature.

During the measurement process, a thermostat bath Haake C10–P5/U with an accuracy of ±0.04 °C was used to maintain constant temperature of samples. The relative error of the experimental data was calculated as 1.52 % and was based on 96 point data for thermal conductivity measurements (i.e. for water, simple nanofluids and hybrid nanofluids at room temperature).



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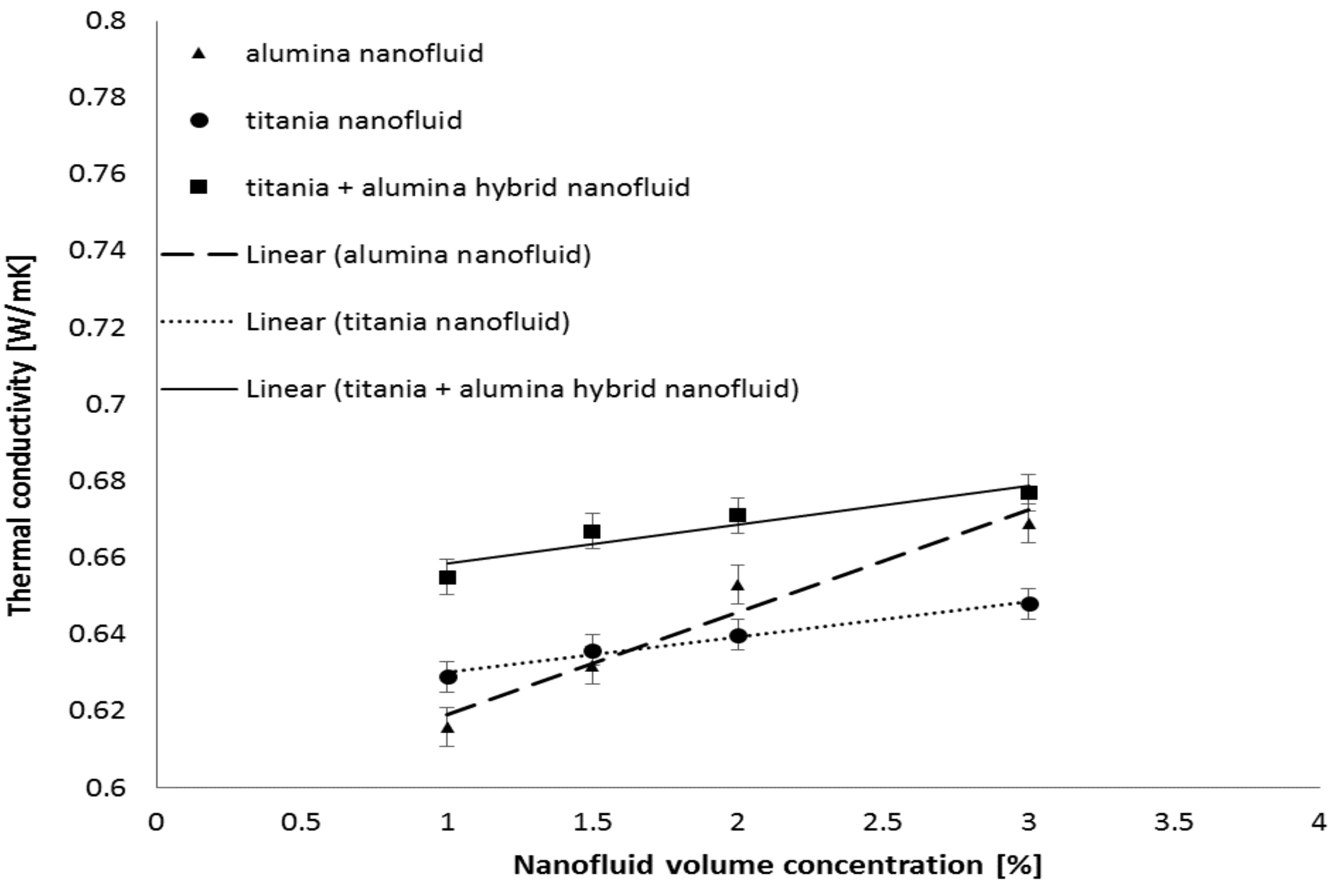
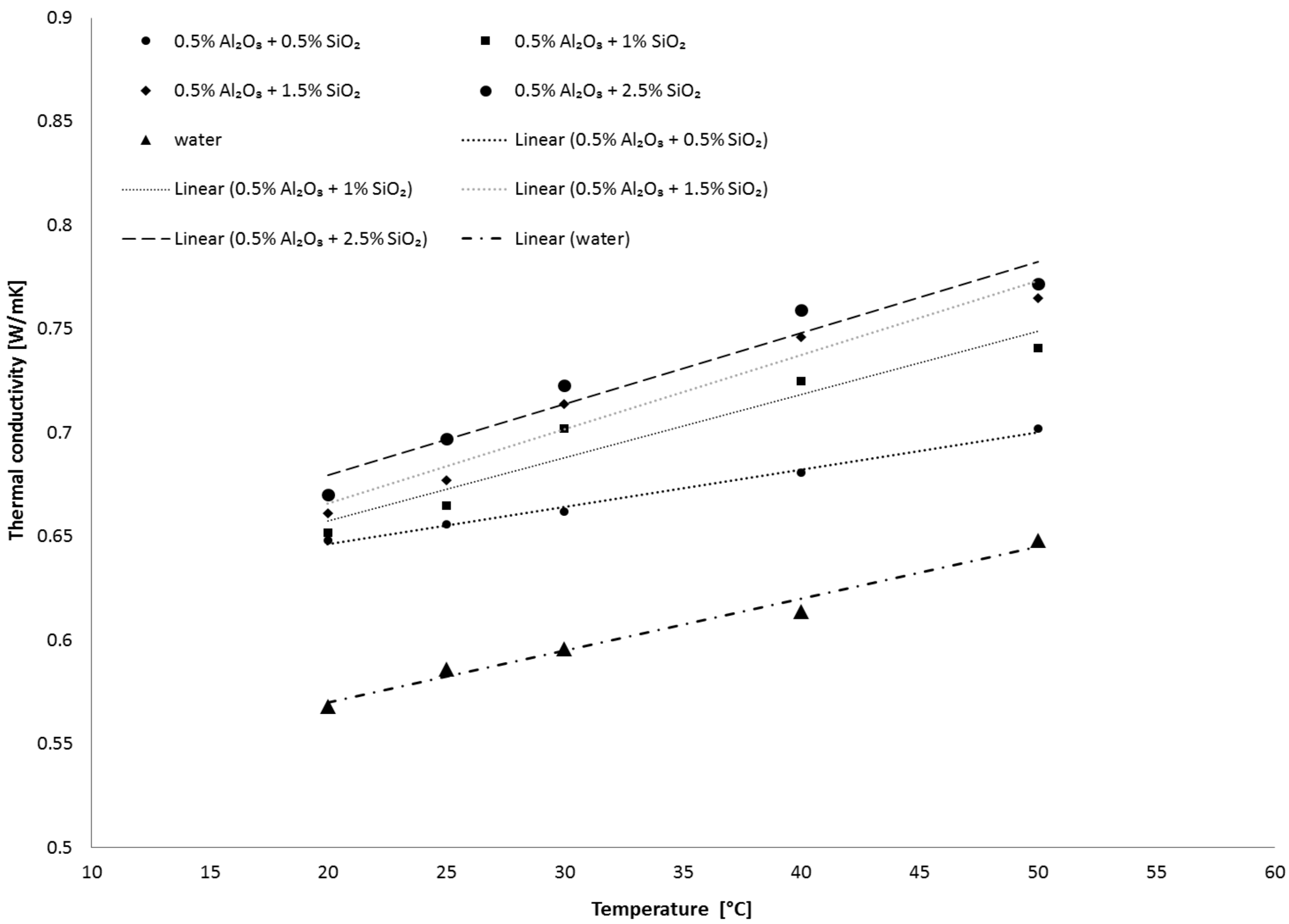
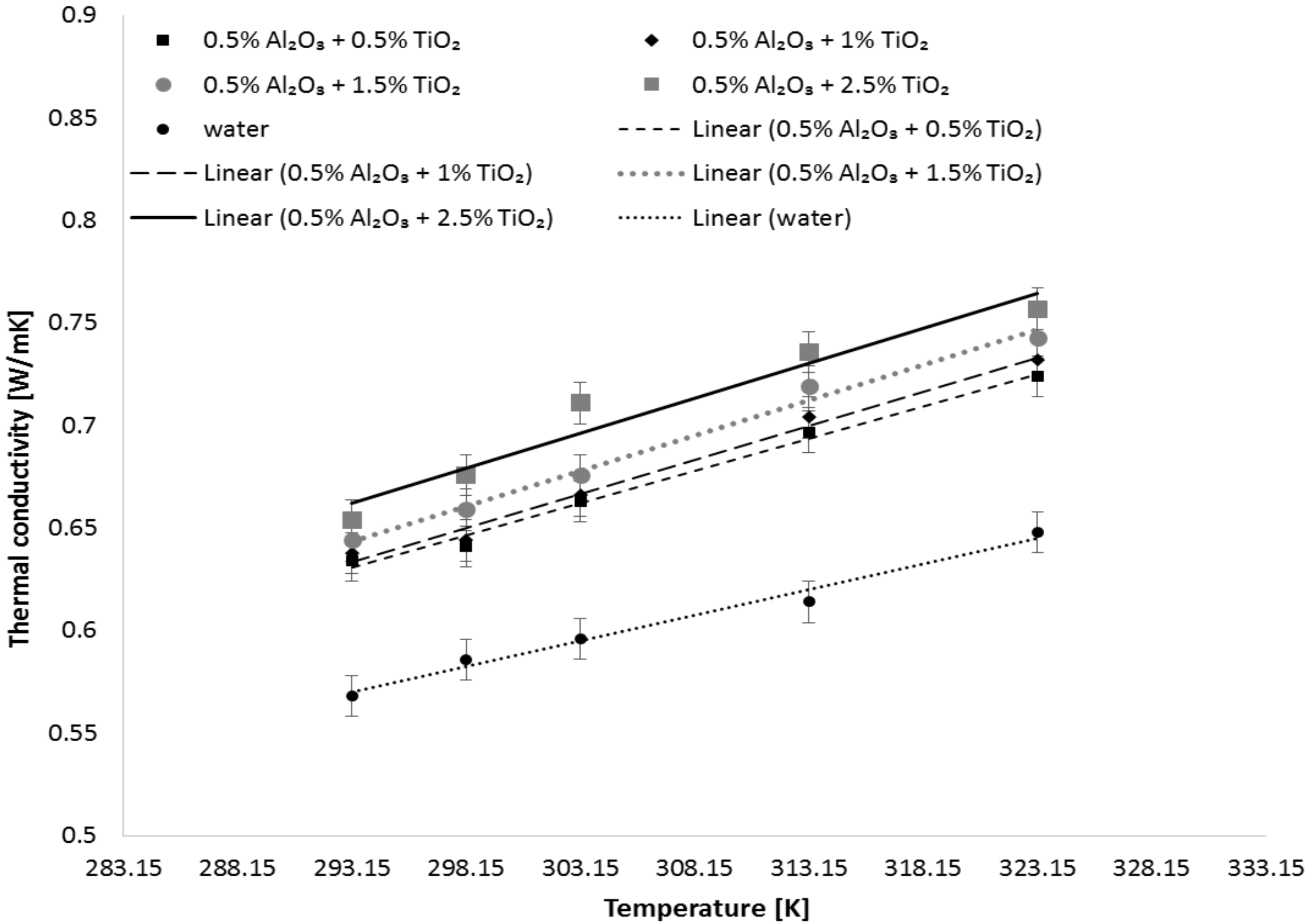

alumina nanofluid
titania nanofluid
titania + alumina hybrid nanofluid
Linear (alumina nanofluid)
Linear (titania nanofluid)
Linear (titania + alumina hybrid nanofluid)
Thermal conductivity [W/mK]
0.8
0.78
0.76
0.74
0.72
0.7
0.68
0.66
0.64
0.62
0.6
0
0.5
1
1.5
2
2.5
3
3.5
4
Nanofluid volume concentration [%]


0.5% Al₂O₃ + 0.5% SiO₂
0.5% Al₂O₃ + 1% SiO₂
0.5% Al₂O₃ + 1.5% SiO₂
0.5% Al₂O₃ + 2.5% SiO₂
water
Linear (0.5% Al₂O₃ + 0.5% SiO₂)
Linear (0.5% Al₂O₃ + 1% SiO₂)
Linear (0.5% Al₂O₃ + 1.5% SiO₂)
Linear (0.5% Al₂O₃ + 2.5% SiO₂)
Linear (water)
Thermal conductivity [W/mK]
Temperature [°C]
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
10
15
20
25
30
35
40
45
50
55
60


0.5% Al_2O_3 + 0.5% TiO_2
0.5% Al_2O_3 + 1% TiO_2
0.5% Al_2O_3 + 1.5% TiO_2
0.5% Al_2O_3 + 2.5% TiO_2
water
Linear (0.5% Al_2O_3 + 0.5% TiO_2)
Linear (0.5% Al_2O_3 + 1% TiO_2)
Linear (0.5% Al_2O_3 + 1.5% TiO_2)
Linear (0.5% Al_2O_3 + 2.5% TiO_2)
Linear (water)
Thermal conductivity [W/mK]
Temperature [K]
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
283.15
288.15
293.15
298.15
303.15
308.15
313.15
318.15
323.15
328.15
333.15

NUMERICAL PROCEDURE

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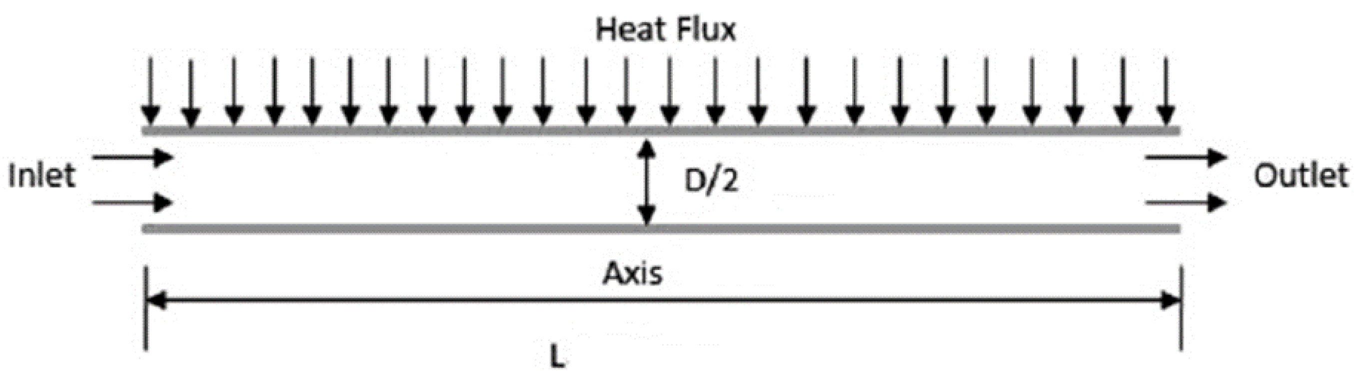
- copper tube with a length L=1.75 m, inner diameter D=0.014 m and outer diameter of 0.016 m.
- the entire copper test section was maintained as constant heat-flux boundary condition by wounding nichrome heater of 20 mm gauge, resistance of 53.3 Ω/m and 1000 W maximum capacity.
- the test section was placed in a straight square channel in order to guarantee horizontality. The gap between the test tube and the square duct is filled with rock wool insulation to reduce the heat loss to atmosphere.
- the aspect ratio (L/D = 125) of the test section is sufficiently large for the flow to be hydrodynamically developed.



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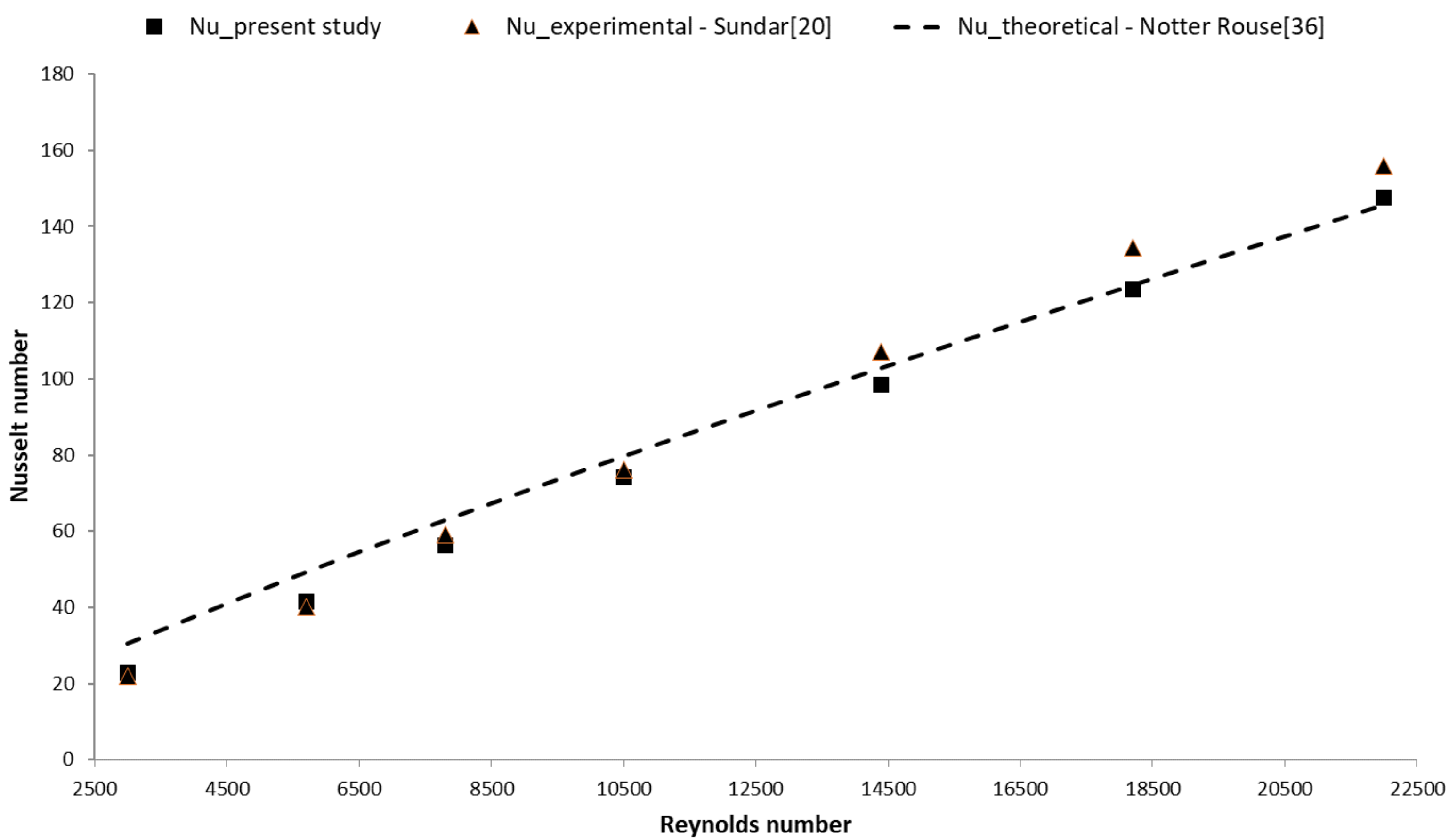

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Nanofluid type	Base fluid	Volume concentration of nanoparticles, %vol.
Single component nanofluids	Water	1.00 % vol. Al_2O_3
		1.00 % vol. SiO_2
		1.00 % vol.TiO_2
Hybrid nanofluids		0.50 % vol.Al_2O_3 + 0.50 % vol. TiO_2
		0.50 % vol.Al_2O_3 + 0.5 % vol.SiO_2

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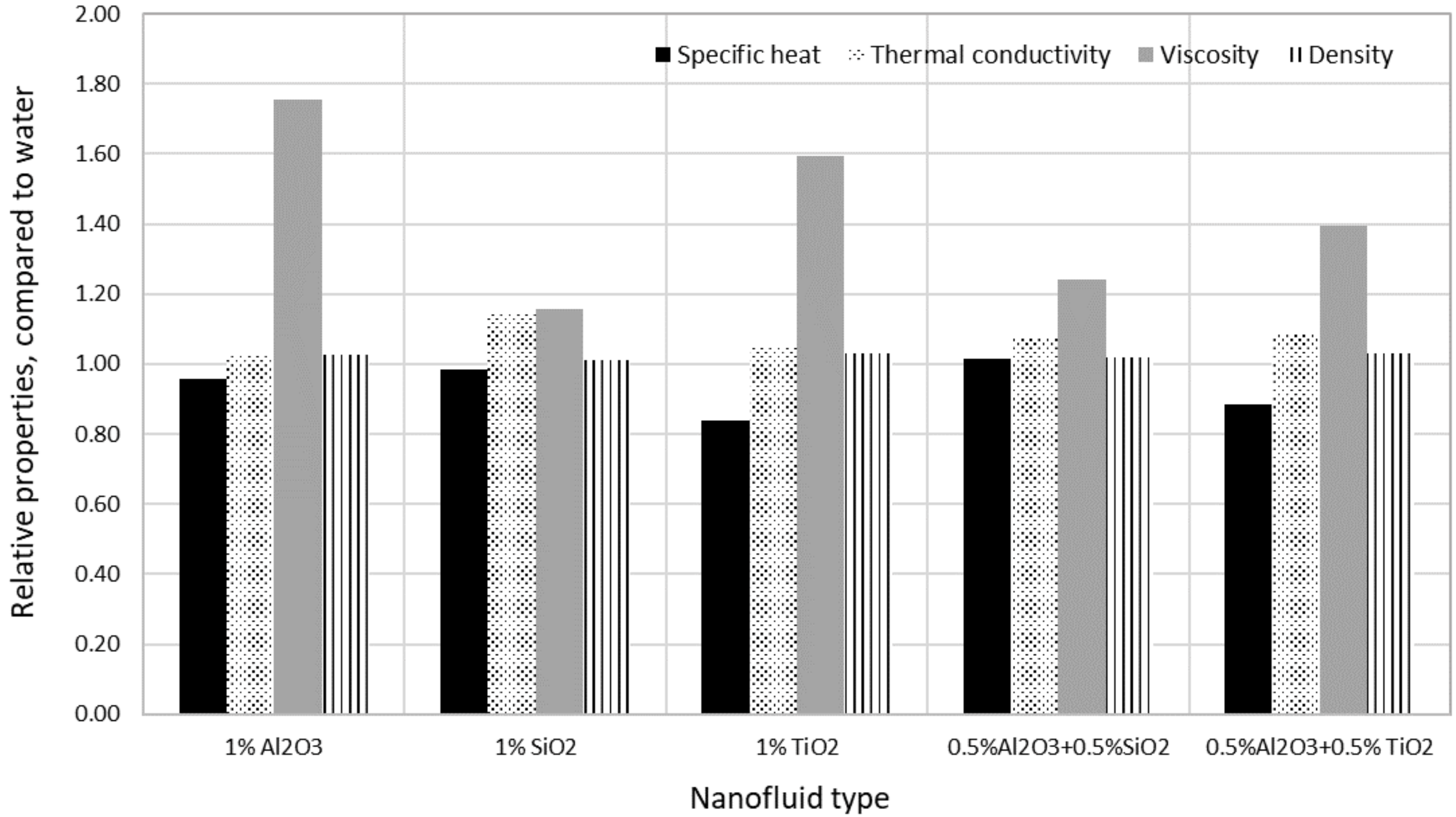
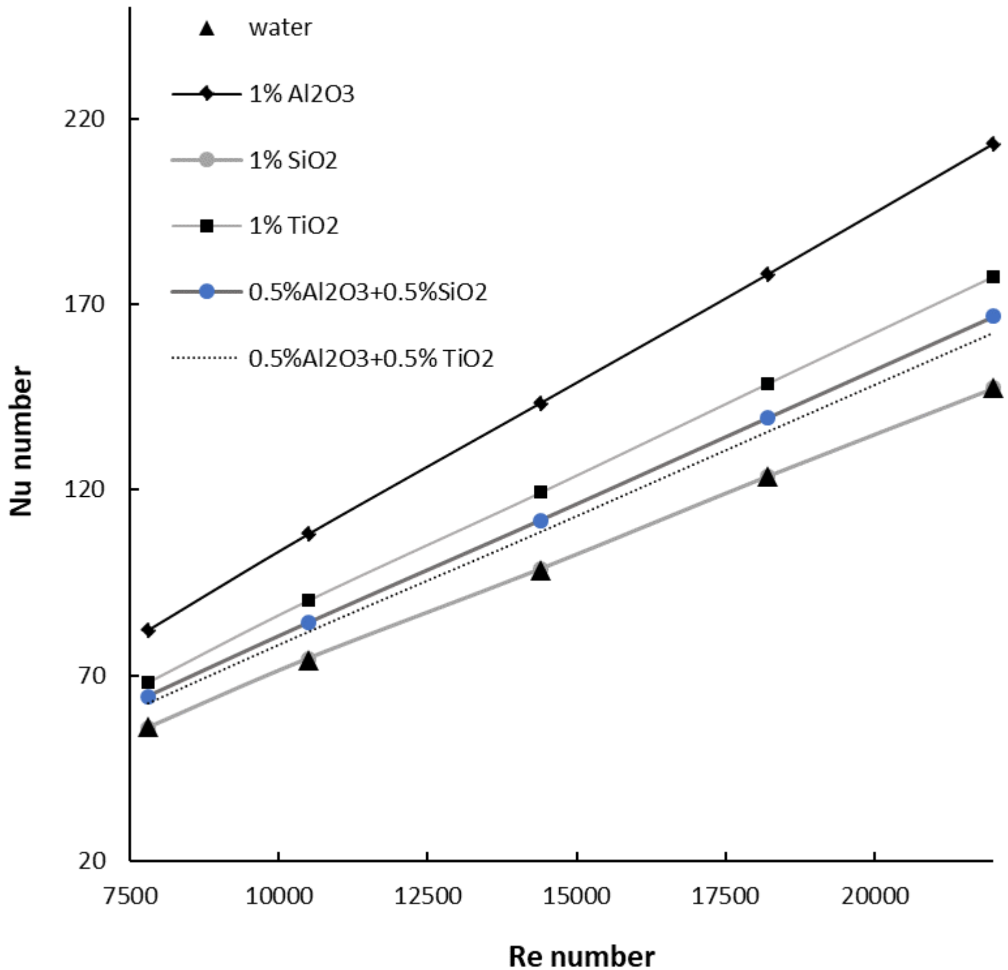
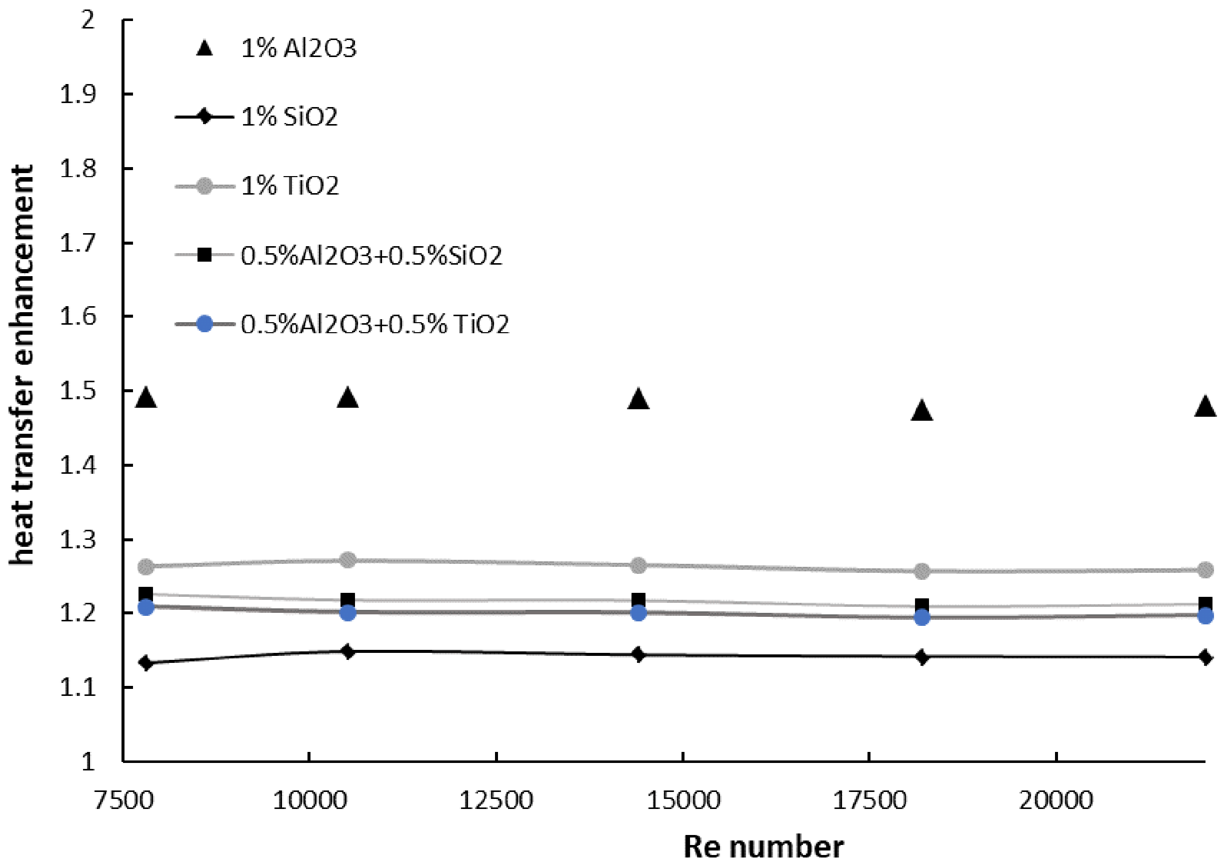

2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Relative properties, compared to water
Specific heat
Thermal conductivity
Viscosity
Density
1% Al2O3
1% SiO2
1% TiO2
0.5%Al2O3+0.5%SiO2
0.5%Al2O3+0.5% TiO2
Nanofluid type


water
1% Al2O3
1% SiO2
1% TiO2
0.5%Al2O3+0.5%SiO2
0.5%Al2O3+0.5% TiO2
Nu number
220
170
120
70
20
7500
10000
12500
15000
17500
20000
Re number



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CONCLUSION

This research start point was the **manufacture of two hybrid nanofluids** followed by a deep experimental study of their thermophysical properties and stability. Further on, all the experimental results were introduced in a numerical analysis to outline the advantages of the new nanoparticle enhanced fluid on a solar collector efficiency if compares to conventional heat transfer fluids.

- ✓ The **heat transfer behavior of different mono and hybrid nanofluids** were numerically studied using a 3D tube model.
- ✓ The analysis revealed that **the influence of nanoparticles type on Nu and heat transfer coefficient is of great importance** when dealing with nanoparticle enhanced new fluids.
- ✓ Results showed an **increased solar collector heat transfer efficiency** depending on the nanoparticles type.
- ✓ **Concluding, it may strongly affirm that the heat transfer performance in a tube is enlarged by suspension of hybrid nanoparticles if compared with that of pure water.** Though, a significant intensification in both experimental and numerical work is desirable in order to shape a relevant theory concerning these new nanoparticle enhanced heat transfer fluids.

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[1]Sajid M. U., Ali H. M., Thermal conductivity of hybrid nanofluids: A critical review, International Journal of Heat and Mass Transfer 126 (2018) 211–234.
[2]Das P. K., A review based on the effect and mechanism of thermal conductivity of normal nanofluids and hybrid nanofluids, Journal of Molecular Liquids 240 (2017) 420–446.
[3]Sidik N. A. C., Adamu I. M., Jamil M. M., Kefayati G.H.R., Mamat R., Najafi G., Recent progress on hybrid nanofluids in heat transfer applications: A comprehensive review, International Communications in Heat and Mass Transfer 78 (2016) 68–79.
[4]Nabil M.F., Azmi W.H., Hamid K.A., Zawawi N.N.M., Priyandoko G., Mamat R., Thermo-physical properties of hybrid nanofluids and hybrid nanolubricants: A comprehensive review on performance, International Communications in Heat and Mass Transfer 83 (2017) 30–39.
[5]Leong K.Y., Ku Ahmad K.Z., Ong H. C., Ghazali M.J., Baharum A., Synthesis and thermal conductivity characteristic of hybrid nanofluids – A review, Renewable and Sustainable Energy Reviews 75 (2017) 868.
[6]Kumar D. D., Arasu A. V., A comprehensive review of preparation, characterization, properties and stability of hybrid nanofluids, Renewable and Sustainable Energy Reviews 81 (2018) 1669–1689.
[7]Khodadadi H., Aghakhani S., Majd H., Kalbasi R., Wongwises S., Afrand M., A comprehensive review on rheological behavior of mono and hybrid nanofluids: Effective parameters and predictive correlations, International Journal of Heat and Mass Transfer 127 (2018) 997–1012.
[8]Sidik N. A. C., Jamil M. M., Japar W. M., Adamu I. M., A review on preparation methods, stability and applications of hybrid nanofluids, Renewable and Sustainable Energy Reviews 80 (2017) 1112–1122.
[9]Hamzah M. H., Sidik N. A. C., Ken T. L., Mamat R., Najafi G., Factors affecting the performance of hybrid nanofluids: A comprehensive review, International Journal of Heat and Mass Transfer 115 (2017) 630.
[10]Huminic G., Huminic A., Heat transfer capability of the hybrid nanofluids for heat transfer applications, Journal of Molecular Liquids 272 (2018) 857–870.
[11]Han W S, Rhi SH, Thermal Characteristics of Grooved Heat Pipe with hybrid nanofluids, Thermal science, 15 (2011) 195-206.
[12]Momin G., Experimental investigation of mixed convection with water-Al2O3 & hybrid nanofluid in inclined tube for laminar flow, International journal of scientific & technology research, 2(2013) 193.
[13]Madhesh D., Kalaiselvam S., Experimental Analysis of Hybrid Nanofluid as a Coolant, Procedia Engineering 97 (2014) 1667 – 1675.
[14]Suresh S, Venkitaraj KP, Selvakumar P, Synthesis of Al2O3– Cu/ water hybrid nanofluids using two step method and its thermophysical properties. Colloids Surf A: Physicochem Eng Asp 388 (2011) 41–8.
[15]Jana S, Khojin AS, Zhong WH. Enhancement of fluid thermal conductivity by the addition of single and hybrid nano-additives. Thermochim Acta 462 (2007) 45–55.
[16]Abbasi SM, Nemati A, Rashidi A, Arzani K. The effect of functionalization method on the stability and the thermal conductivity of nanofluid hybrids of carbon nanotubes. Ceram Int; 39 (2013) 3885–91.
[17]Munkhbayar B, Tanshen MR, Jeoun J, Chung H, Jeong H. Surfactant-free dispersion of silver nanoparticles into MWCNT- aqueous nanofluids prepared by one-step technique and their thermal characteristics. Ceram Int 39 (2013) 6415–25.
[18]Nine MJ, Rahman MS, Chung H, Jeong H. Highly productive synthesis process of well dispersed Cu2O and Cu/Cu2O nanoparticles and its thermal characterization. Mater Chem Phys 141(2013) 636–42.
[19]Chen LF, Cheng M, Yang DJ, Yang L. Enhanced thermal conductivity of nanofluid by synergistic effect of multi-walled carbon nanotubes and Fe2O3 nanoparticles. Appl Mech Mater 548–549 (2014) 118–23.
[20]Sundar LS, Singh MK, Sousa, ACM, Enhanced heat transfer and friction factor of MWCNT–Fe3O4/water hybrid nanofluids, International Communications in Heat and Mass Transfer 52 (2014) 73–83.
[21]Baby T.T., Ramaprabhu S., Surfactant free magnetic nanofluids based on core-shell type nanoparticle decorated multiwalled carbon nanotubes, J. Appl. Phys. 110 (2011) 064325–064331.
[22]Nimmagadda R., Venkatasubbaiah K., Conjugate heat transfer analysis of micro-channel using novel hybrid nanofluids (Al2O3 + Ag/Water), European Journal of Mechanics B/Fluids 52 (2015) 19–27.
[23]Esfe M.H., Abbasian Arani A.A., Rezaie M., Yan W-M, Karimipour A., Experimental determination of thermal conductivity and dynamic viscosity of Ag–MgO/water hybrid nanofluid, International Communications in Heat and Mass Transfer 66 (2015) 189–195.
[24]Moghadassi A, Ghomi E, Parvizian F, A numerical study of water based Al2O3 and Al2O3-Cu hybrid nanofluid effect on forced convective heat transfer, Int. Journal of Thermal Sciences 92 (2015) 50-57.
[25]Madhesh D., Parameshwaran R., Kalaiselvam S., Experimental investigation on convective heat transfer and rheological characteristics of Cu–TiO2 hybrid nanofluids, Exp. Therm Fluid Sci. 52 (2014) 104–115.
[26]Balla SS, Abdullah S,Mohd Fairzal W, Zulkifli R., Sopian K, Numerical study of the enhancement of heat transfer for hybrid CuO-Cu nanofluids flowing in a circular pipe. Journal of Oleo Science, 62 (2013) 533
[27]Moldoveanu, G.M., Minea, A.A., Huminic, G., Huminic, A., Al2O3/TiO2 hybrid nanofluids thermal conductivity: an experimental approach, Journal of Thermal Analysis and Calorimetry,, 2018
[28]Moldoveanu, G.M., Huminic, G., Minea, A.A., Huminic, A., Experimental study on thermal conductivity of stabilized Al2O3 and SiO2 nanofluids and their hybrid, Int J of Heat and Mass Trans127 (2018) 450.
[29]Moldoveanu G.M., Ibanescu C, Danu M., Minea A.A., Viscosity estimation of Al2O3, SiO2 nanofluids and their hybrid: An experimental study, Journal of Molecular Liquids, 253 (2018) 188-196.
[30]Moldoveanu G.M., Minea A.A., Iacob M, Ibanescu C, Danu M., Experimental study on viscosity of stabilized Al2O3, TiO2 nanofluids and their hybrid, Thermochimica Acta, 659 (2018) 203–212.
[31]Minea A.A., Moldoveanu M. G., Dodun O., Thermal Conductivity Enhancement by Adding Nanoparticles to Ionic Liquids, Precision Machining IX, Solid State Phenomena 261 (2017) 121-126.
[32]Minea A.A., Moldoveanu M.G., Studies on Al2O3, CuO and TiO2 water based nanofluids: a comparative approach in laminar and turbulent flow, Journal of engineering thermophysics, 26 (2017) 291-301.
[33]Pak B.C., Cho Y.I., Hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide particles, Exp. Heat Transfer 11 (1998) 151–170.
[34]Minea A.A., Challenges in hybrid nanofluids behavior in turbulent flow: Recent research and numerical comparison, Renewable and Sustainable Energy Reviews, 71 (2017) 426–434.
[35]Minea A.A., Numerical studies on heat transfer enhancement and synergy analysis on few metal oxide water based nanofluids. International Journal of Heat and Mass Transfer 89 (2015): 1207-1215.
[36]Notter R.H., Rouse M.W., A solution to the Graetz problem—III. Fully developed region heat transfer rates, Chem. Eng. Sci. 27 (1972) 2073–2093.

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