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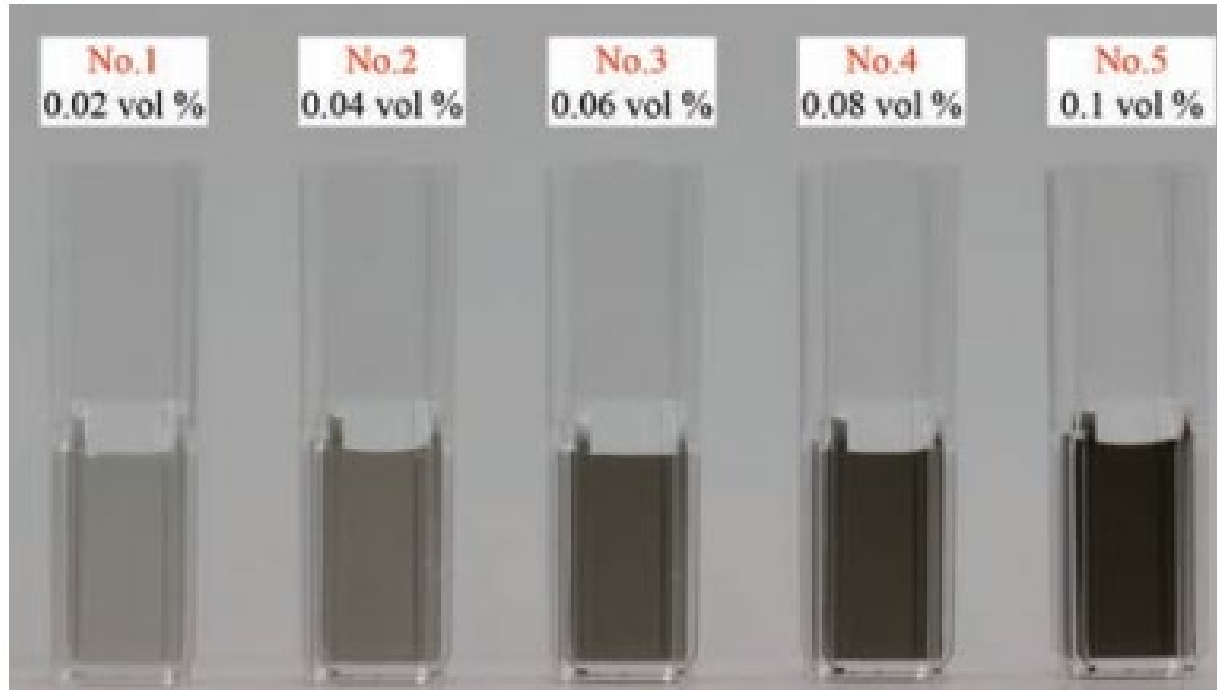
PRIČA O NANOFUIDIMA

Vebinar u organizaciji Saveza Hemijskih Inženjera Srbije

Dr Siniša Bikić, vanr. prof.

Nanofluid je tečnost koja sadrži čestice nanometarske veličine koje se nazivaju nanočestice.

Nanofluidi su inženjerske koloidne suspenzije nanočestica u osnovnom fluidu.



Xinzhi Wang, Yanwei Hu, Tianyu Li, and Yurong He (2017), Experimental Investigation of Graphene Nanofluid and Numerical Simulation of Its Natural Convection in a Square Enclosure, Nanoscience and Nanotechnology Letters, Vol. 9, 640–649.

Fig. 1. Digital photograph of GNS nanofluids dispersion with different volume fractions.

Choi, S.U., Eastman, J.A., (1995). Enhancing Thermal Conductivity of Fluids with Nanoparticles, Tech. rep. Argonne National Lab., IL (United States).

ENHANCING THERMAL CONDUCTIVITY OF FLUIDS WITH NANOPARTICLES

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¹Energy Technology Division and ²Materials Science Division
Argonne National Laboratory
Argonne, Illinois

ABSTRACT

Low thermal conductivity is a primary limitation in the development of energy-efficient heat transfer fluids that are required in many industrial applications. In this paper we propose that an innovative new class of heat transfer fluids can be engineered by suspending metallic nanoparticles in conventional heat transfer fluids. The resulting "nanofluids" are expected to exhibit high thermal conductivities compared to those of currently used heat transfer fluids, and they represent the best hope for enhancement of heat transfer. The results of a theoretical study of the thermal conductivity of nanofluids with copper nanophase materials are presented, the potential benefits of the fluids are estimated, and it is shown that one of the benefits of nanofluids will be dramatic reductions in heat exchanger pumping power.

NOMENCLATURE

d	Pipe diameter
f	Fanning friction factor
h	Heat transfer coefficient
k	Thermal conductivity
L	Length
n	Shape factor
Nu	Nusselt number
P	Pumping power
Pr	Prandtl number
Re	Reynolds number
v	Velocity
α	Particle volume fraction
δp	Pressure drop
ρ	Density
ψ	Sphericity

Subscripts

eff	Effective
m	Metallic particle
nf	Nanofluid
o	Reference fluid without nanoparticles

INTRODUCTION

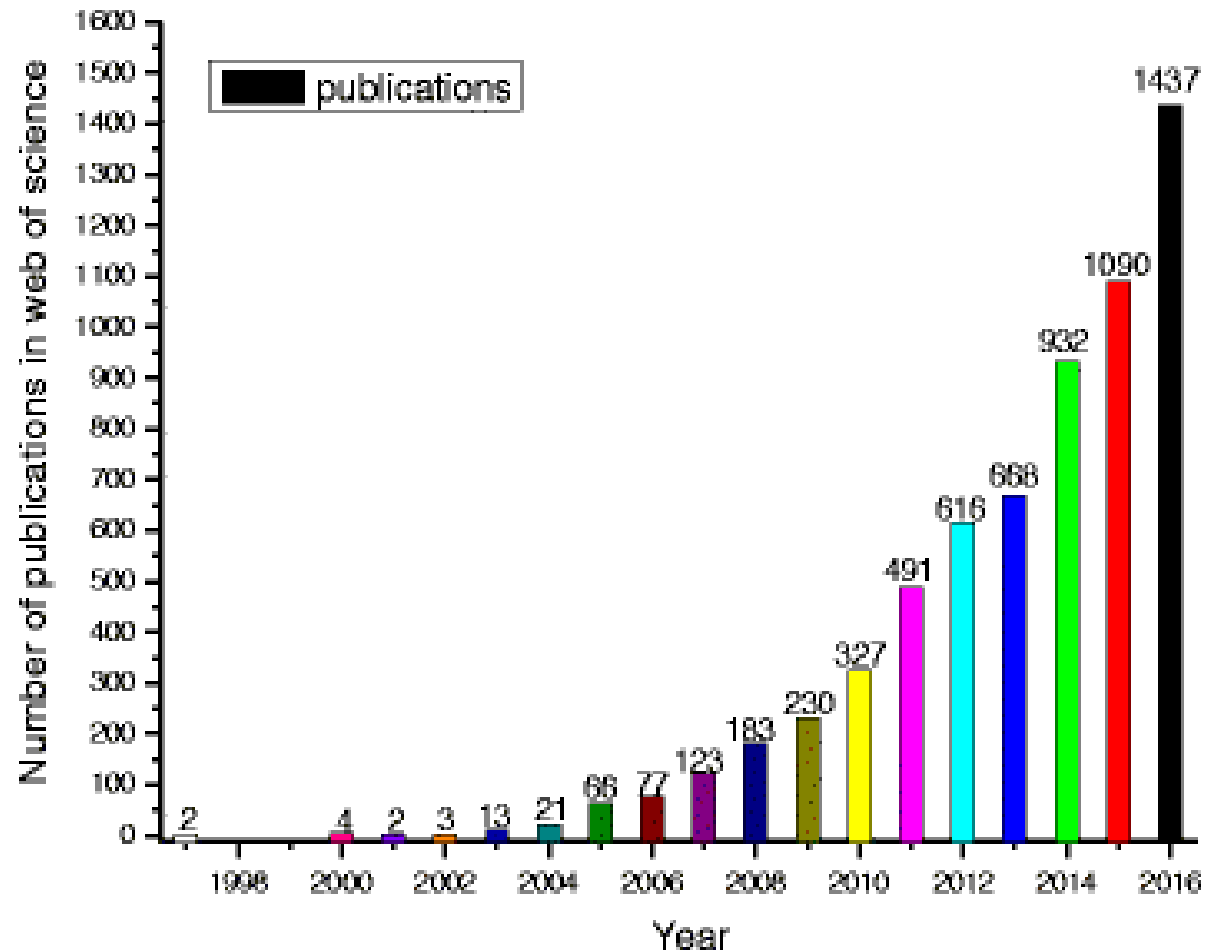
Fluids are often used as heat carriers in heat transfer equipment. Examples of important uses of heat transfer fluids include vehicular and avionics cooling systems in the transportation industry, hydronic heating and cooling systems in buildings, and industrial process heating and cooling systems in petrochemical, textile, pulp and paper, chemical, food, and other processing plants. In all of these applications, the thermal conductivity of heat transfer fluids plays a vital role in the development of energy-efficient heat transfer equipment. With an increasing global competition, industries have a strong need to develop advanced heat transfer fluids with significantly higher thermal conductivities than are presently available.

Despite considerable previous research and development efforts on heat transfer enhancement, major improvements in cooling capabilities have been constrained because of the low thermal conductivity of conventional heat transfer fluids. However, it is well known that at room temperature, metals in solid form have orders-of-magnitude larger thermal conductivities than fluids. For example, the thermal conductivity of copper at room temperature is ≈ 700 times greater than that of water and ≈ 3000 times greater than that of engine oil, as shown in Table 1. The thermal conductivity of metallic liquids is much greater than that of nonmetallic liquids. Therefore, the thermal conductivities of fluids that contain suspended solid metallic particles are expected to be significantly enhanced when compared with conventional

Nanofluidi mogu poboljšati sledeća fizička svojstva u poređenju sa baznom tečnošću:

- toplotnu provodljivost
- specifičnu toplotu
- koeficijent prelaza toplote
- apsorbciju
- indekst refrakcije
- mazivost
- električnu provodljivost i dr.

Yang, L., Yuhan, H.T., (2017). TiO₂ Nanofluids—Part 1: Preparation and Properties
Nanoscale Research Letters, 12, 417, 1-21



Broj radova koji sadrže u naslovu termine
“nanofluids or nanofluid” (“web of science”)

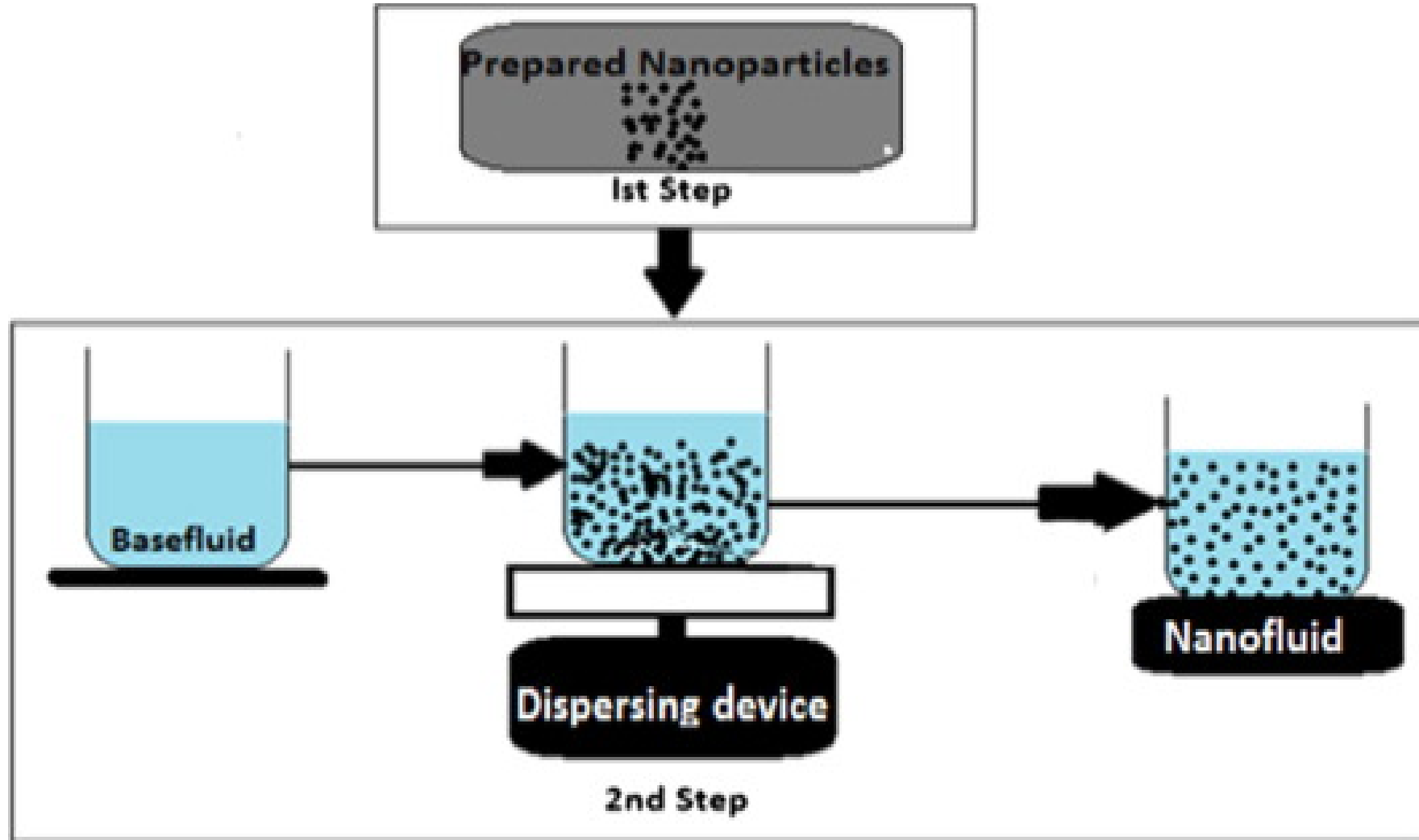
Nanočestice koje se obično koriste u nanofluidima su obično napravljene od:

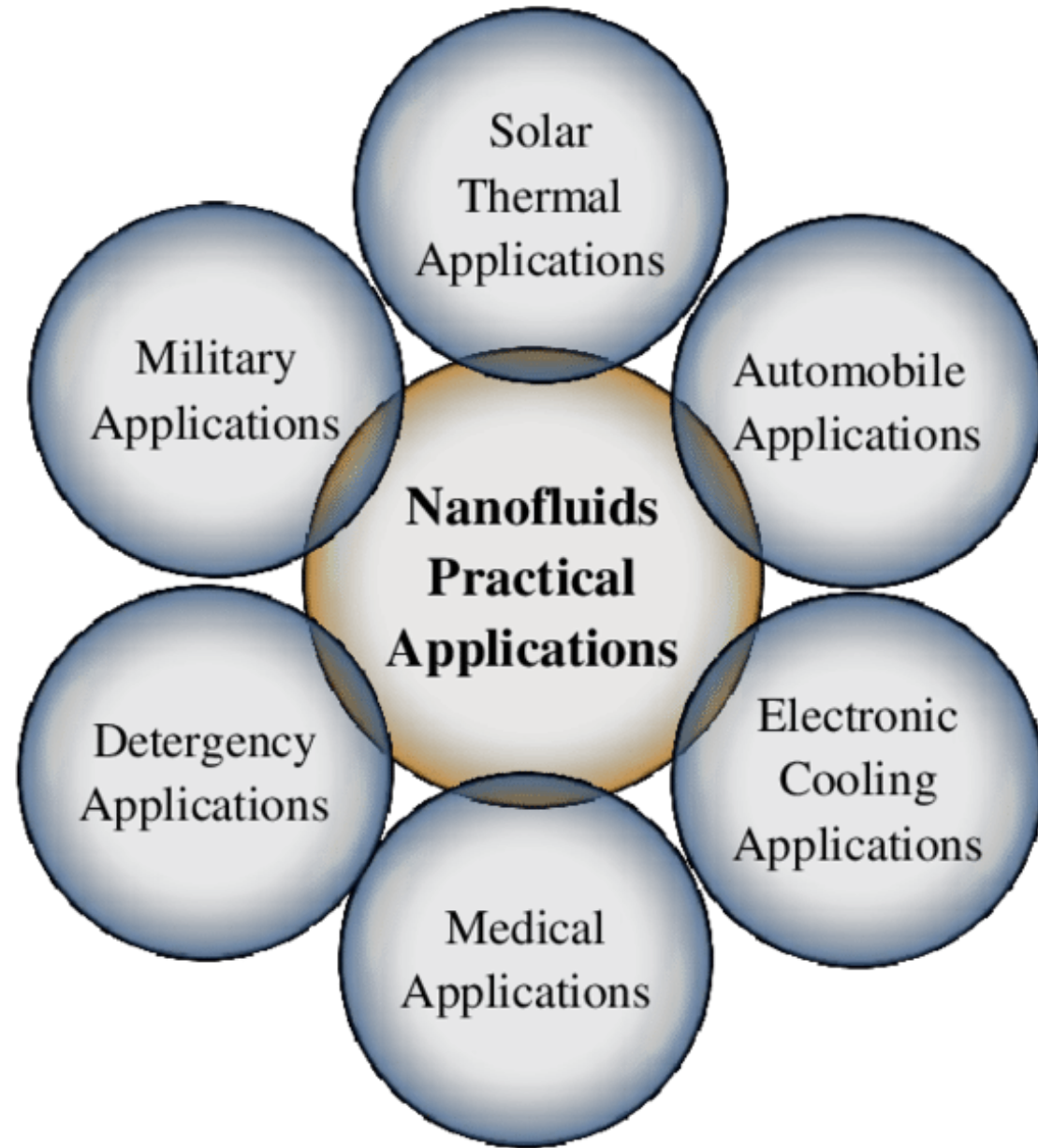
- metali
- oksidi
- karbidi
- nitridi i
- ugljenične nano cevi.

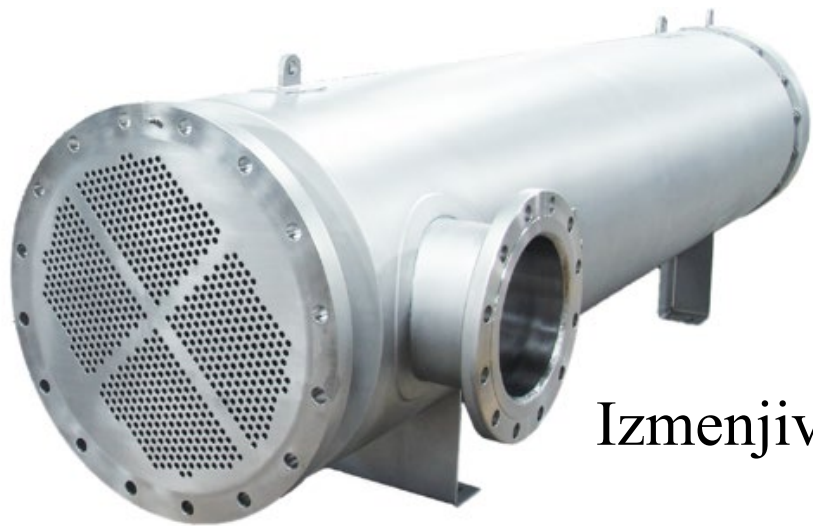
Bazne tečnosti koje se obično koriste u nanofluidima su:

- voda
- etilen glikol
- ulje i
- jonske tečnosti.

Priprema nanofluida metodom u dva koraka.







Izmenjivači toplote



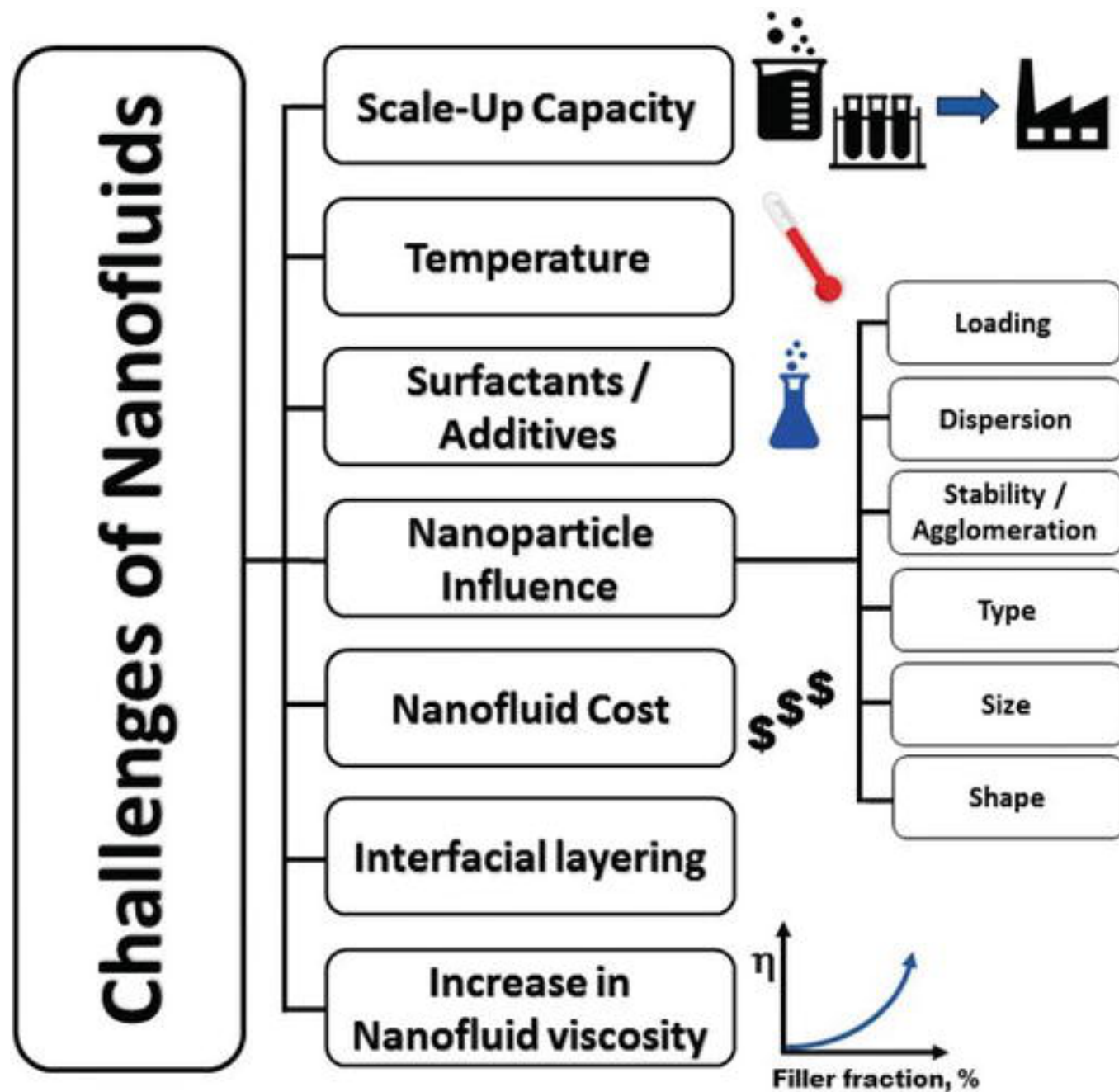
Akumulatori toplote



Solarni kolektor



Hidraulika



Izazovi vezani za nanofluide

Kriterijumi

$$\frac{\mu_{nf}}{\mu_{bf}} = 1 + 39.11\varphi + 533.9\varphi^2 = 1 + C_{\mu}\varphi$$

$$\frac{k_{nf}}{k_{bf}} = \left[\frac{k_{np}(1 + 2\alpha) + 2k_{bf} - 2\varphi(k_{bf} - k_{np}(1 - \alpha))}{k_{np}(1 + 2\alpha) + 2k_{bf} - \varphi(k_{bf} - k_{np}(1 - \alpha))} \right] = 1 + C_k\varphi$$

$$\frac{C_{\mu}}{C_k} < 4$$

Prasher, R., Song, D., Phelan, J., (2006). Measurements of nanofluid viscosity and its implications for thermal applications. Appl. Phys. Lett. 89, 133-108.

$$\frac{k_{nf}}{k_{bf}} > \left(\frac{\mu_{nf}}{\mu_{bf}} \right)^{1/3}$$



Ethylene glycol based silicon nitride nanofluids: An experimental study on their thermophysical, electrical and optical properties

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Thermal conductivity
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ABSTRACT

This paper presents the results of an experimental investigation into the basic physical properties of silicon nitride (Si_3N_4) – ethylene glycol (EG) nanofluids. Samples with various volume fractions of nanoparticles were prepared using a two step method. Basic physical properties such as viscosity, thermal conductivity, electrical conductivity and optical properties were examined. A rheological investigation showed that silicon nitride ethylene glycol nanofluids present non-Newtonian shear thinning behavior. Thermal conductivity indicates a linear dependence on the volume fraction. As well as thermal conductivity increasing with increasing volume fraction, electrical conductivity is also related with the volume fraction of nanoparticles, and this relation is both very strong and nonlinear. The refractive index increases linearly with the volume fraction of nanoparticles in these nanofluids. Finally, it has been found that absorption of examined nanofluids is improved as the volume fraction of nanoparticles increases, especially in the UV region.

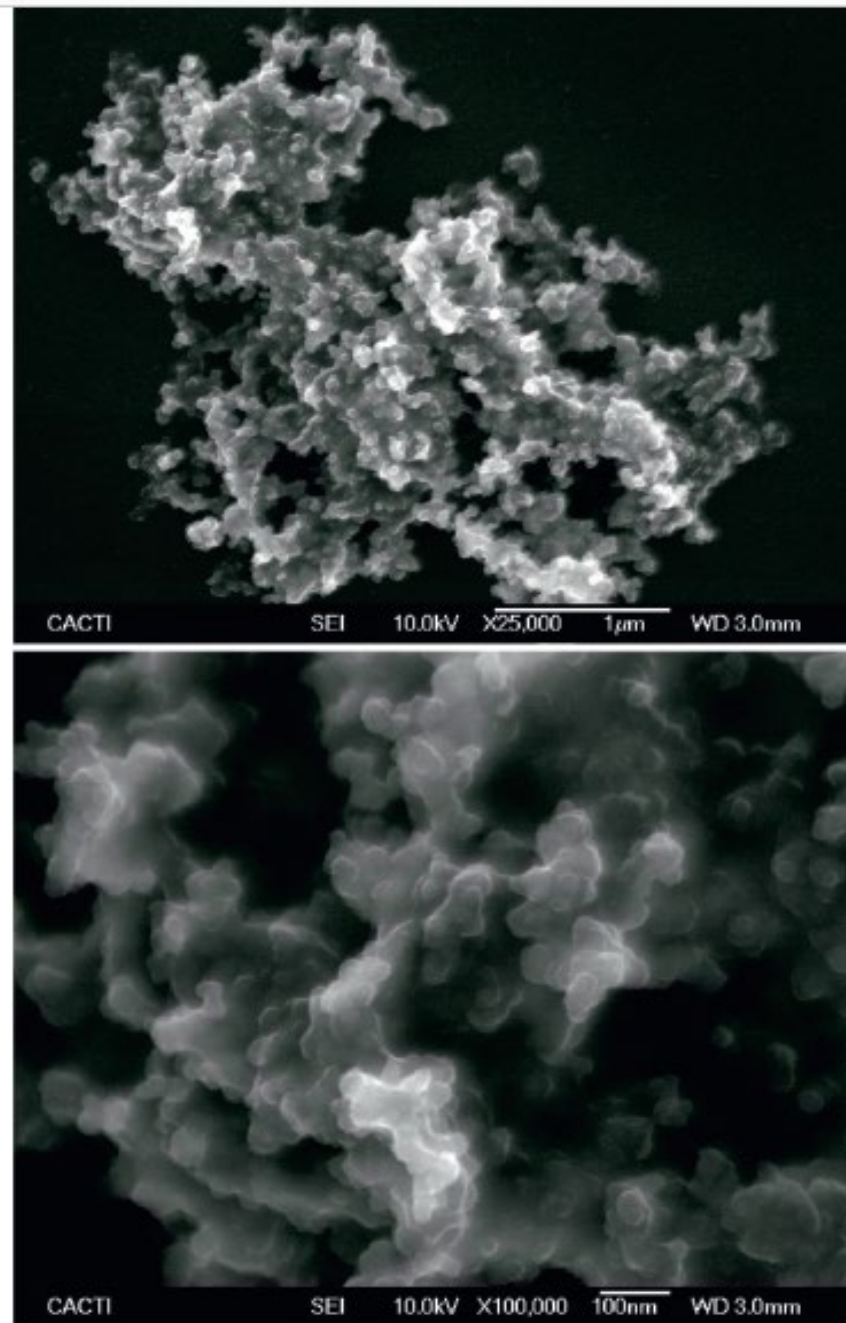
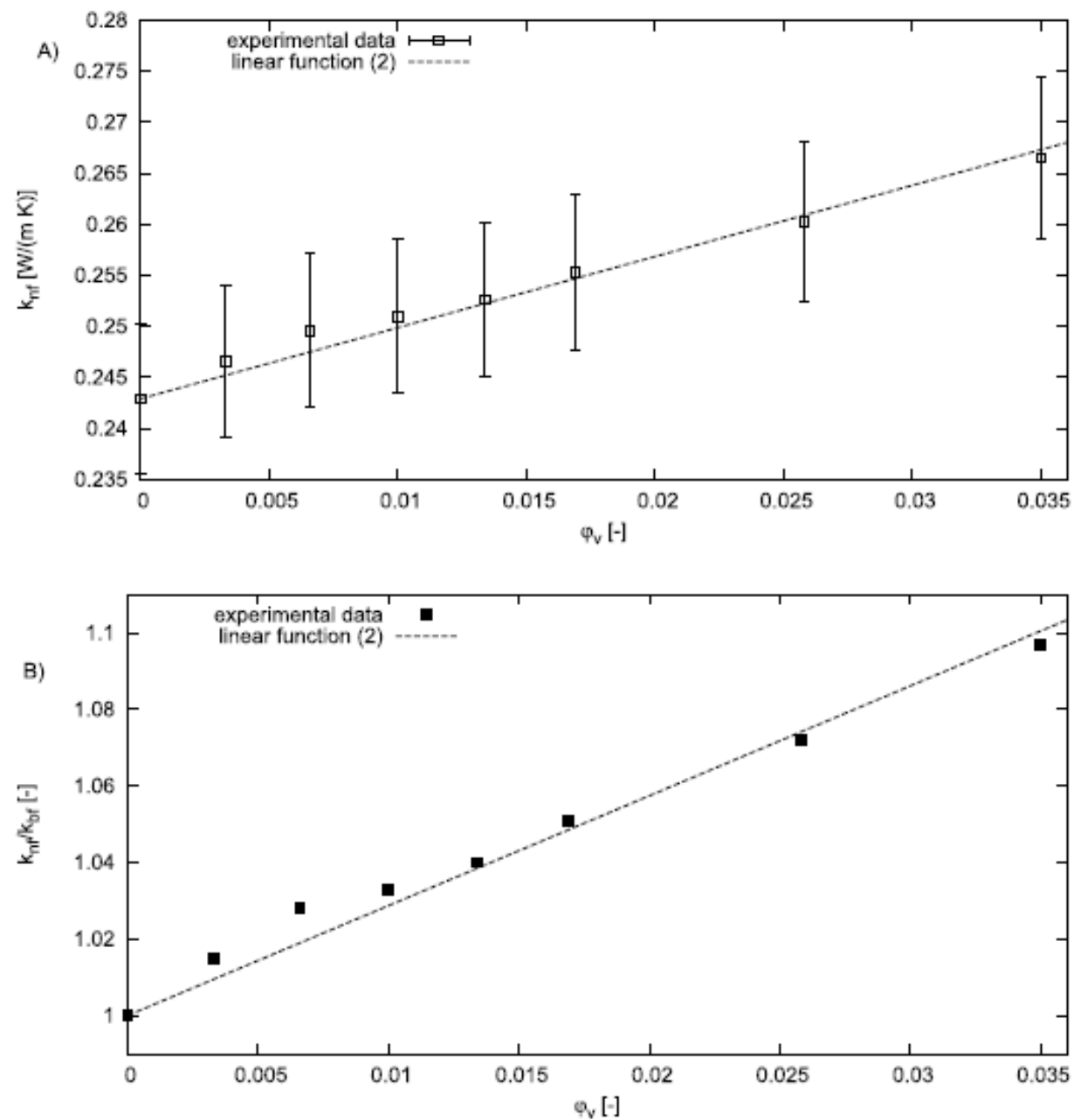


Fig. 1. Scanning electron microscope pictures of dry nanoparticles.



$$\frac{k_{nf}}{k_{bf}} = 1 + 2.87\phi_v.$$

Fig. 4. Dependence of A) thermal conductivity, and B) thermal conductivity ratio on volume fraction of nanoparticles in Si_3N_4 -EG nanofluids at 295.15 K.

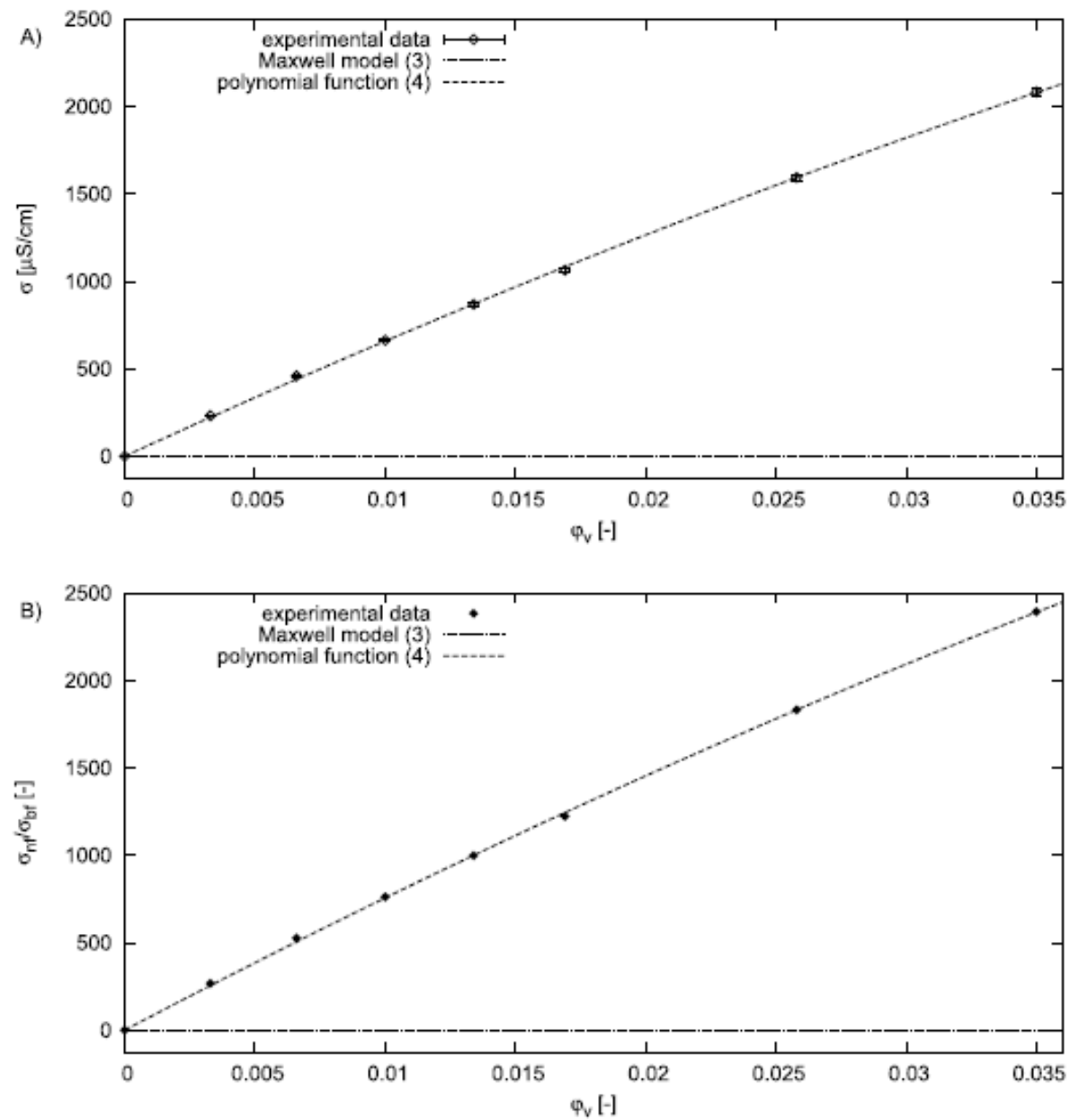
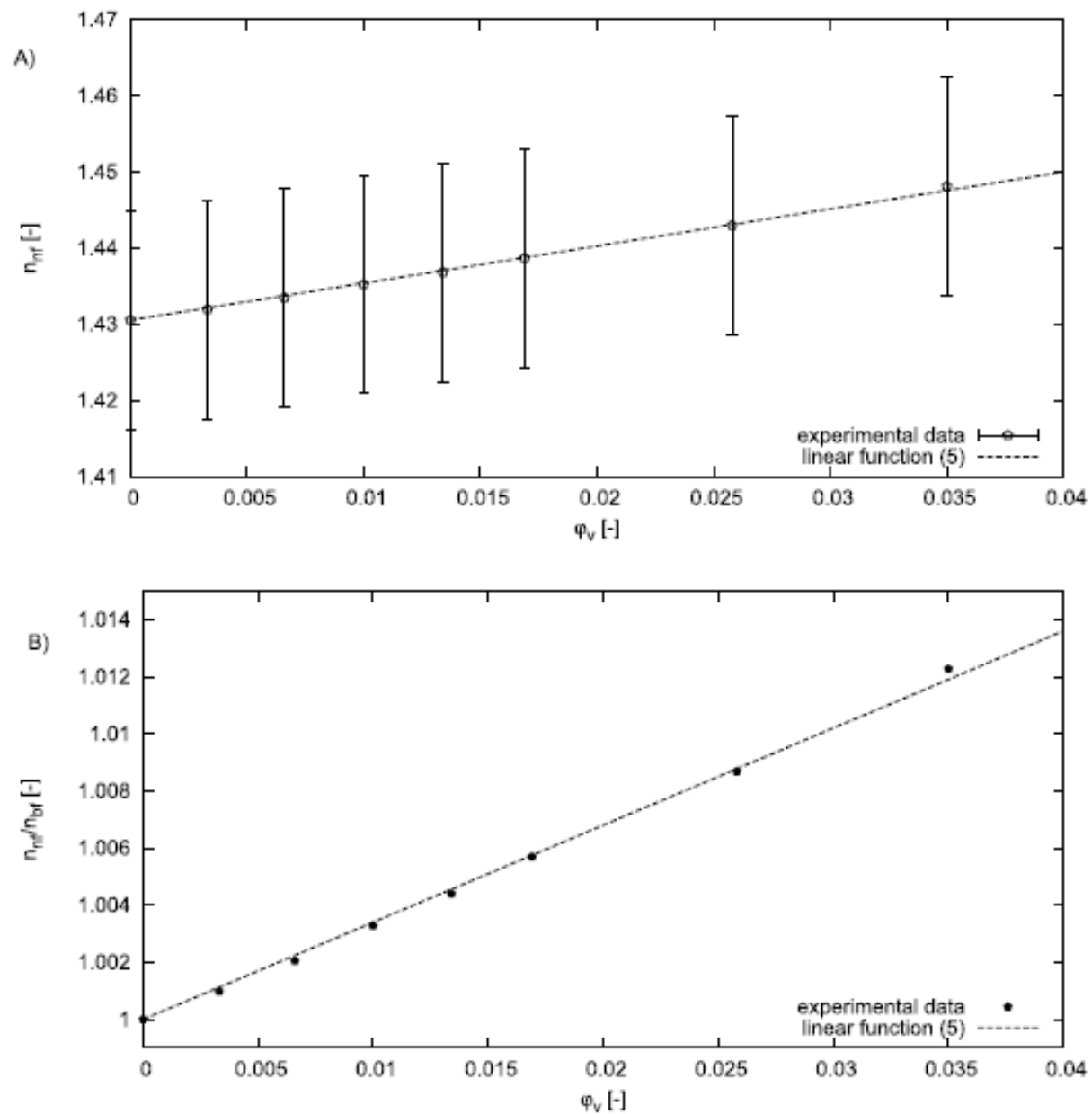


Fig. 5. Dependence of A) electrical conductivity, and B) electrical conductivity ratio on volume fraction of nanoparticles in Si_3N_4 -EG nanofluids at 298.15 K.



$$\frac{n_{nf}}{n_{bf}} = 1 + 0.34\phi_v.$$

Fig. 6. Dependence of A) refractive index, and B) refractive index ratio on volume fraction of nanoparticles in Si_3N_4 -EG nanofluids at 298.15 K.

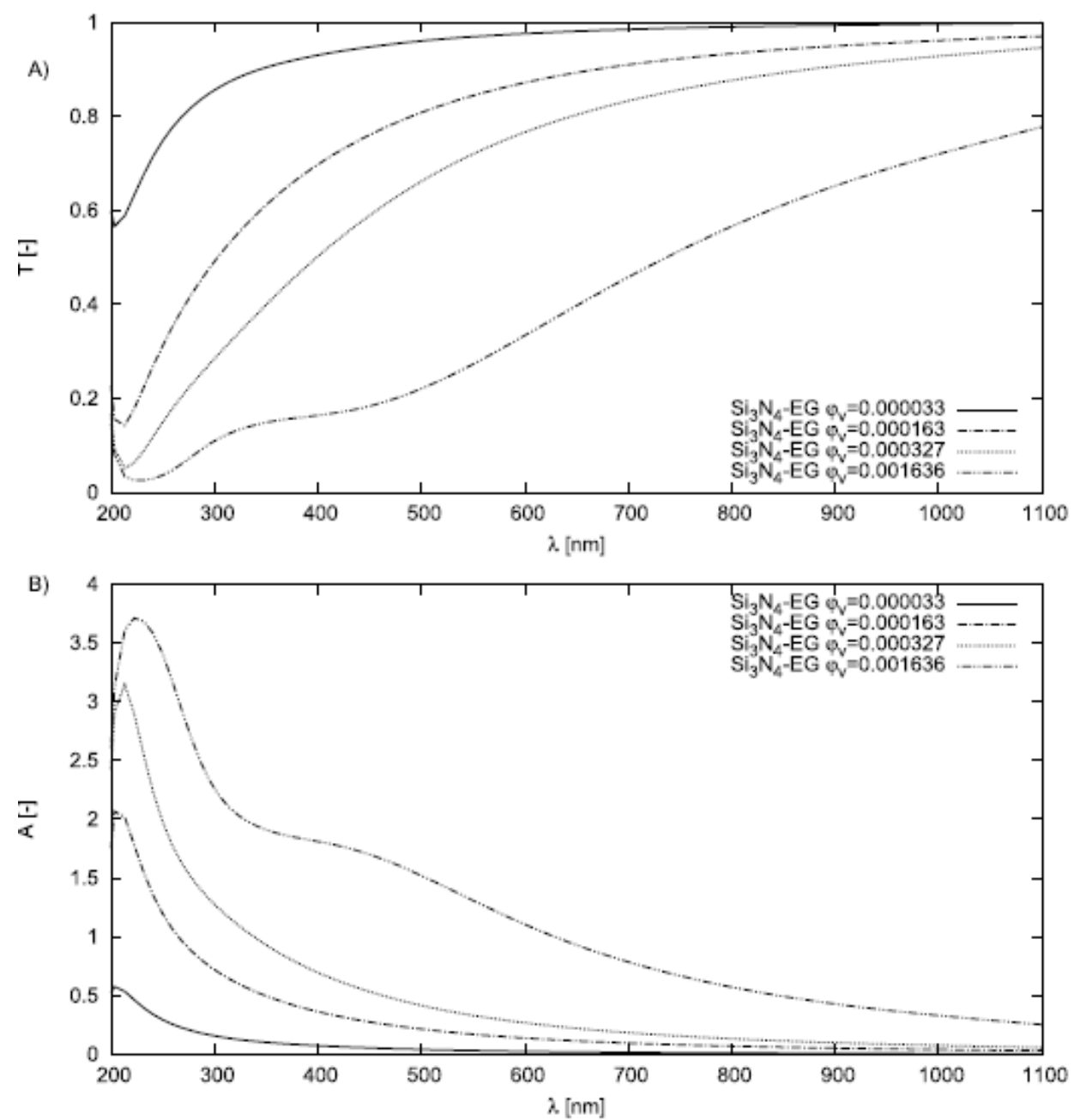


Fig. 7. Dependence of A) transmittance, and B) absorbance on wavelength for Si_3N_4 -EG nanofluids.

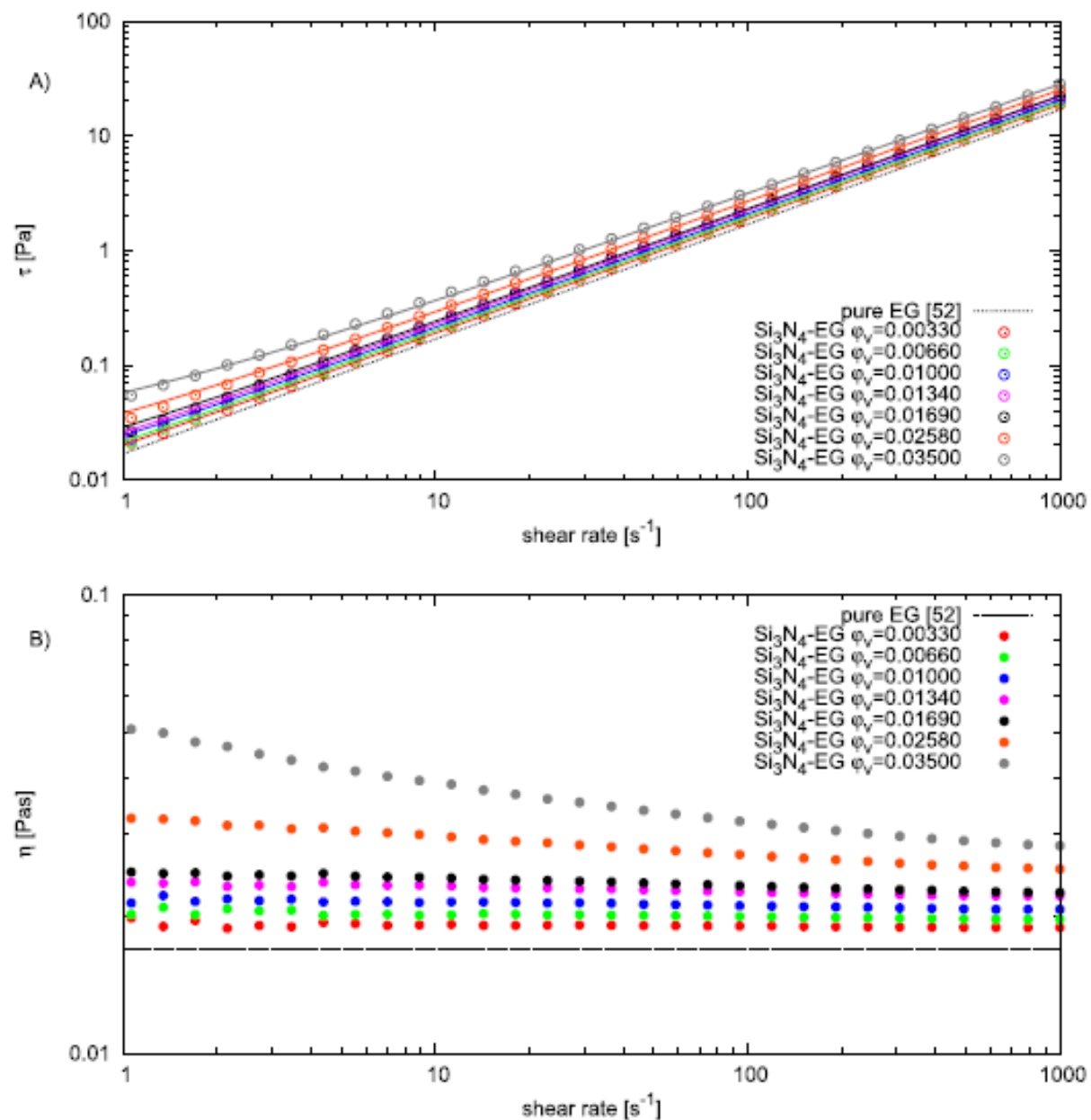


Fig. 2. Dependence of A) shear stress, and B) viscosity on shear rate (flow and viscosity curves respectively) for Si_3N_4 -EG at 298.15 K. Symbols represent measuring points, lines – Herschel-Bulkley model (1).

$$\tau = \tau_0 + K\dot{\gamma}^N.$$

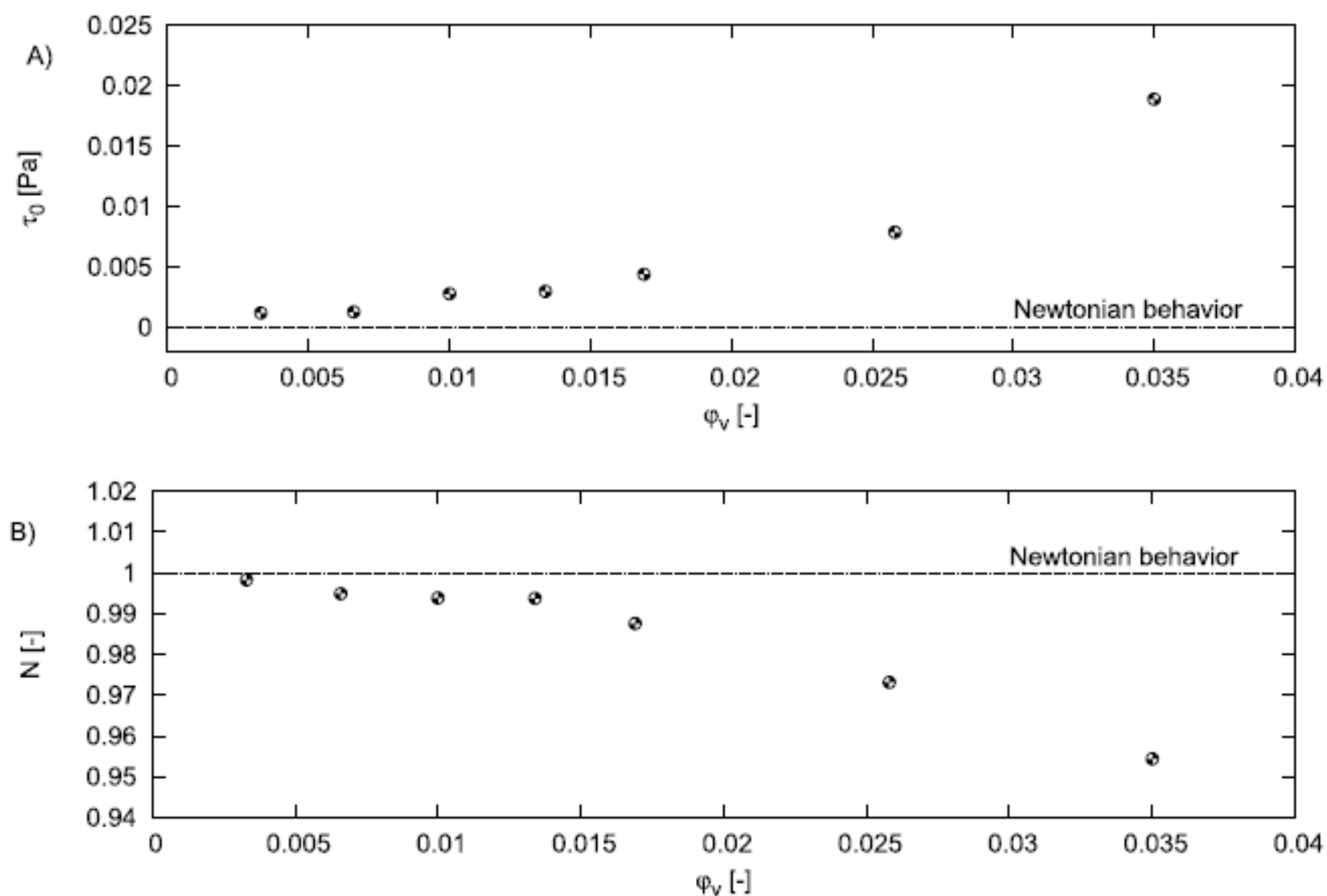


Fig. 3. Herschel-Bulkley model A) yield stress, and B) flow index behavior at various volume fraction of nanoparticles for Si₃N₄-EG nanofluids at 298.15 K.



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Isobaric heat capacity and density of ethylene glycol based nanofluids containing various nitride nanoparticle types: An experimental study



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ABSTRACT

This work presents experimental results on the isobaric heat capacity of ethylene glycol (EG) based nanofluids containing three types of nitride nanoparticles: aluminium nitride (AlN), silicon nitride (Si_3N_4) and titanium nitride (TiN). The densities of the nanofluids were also investigated in this study. Each type of material was used in two different sizes of nanoparticles and with various values of specific surface area. Temperature-modulated differential scanning calorimetry and vibrating tube techniques were used, and measurements were performed at three different temperatures: 288.15 K, 298.15 K and 308.15 K. The obtained experimental results were compared with the predictions of theoretical models, and absolute average deviations were calculated. It was demonstrated that the fraction of nanoparticles strongly affects isobaric heat capacity and density, while the size of the particles does not significantly impact these properties.

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$$\rho_{nf} = (1 - \varphi_v) \rho_{bf} + \varphi_v \rho_p,$$

Table 2

Experimental values of density of ethylene glycol based nanofluids containing various types of nitride nanoparticles at various fractions and temperatures.

T K	φ_m –	AlN20-EG	AlN50-EG	Si ₃ N ₄ 20-EG	Si ₃ N ₄ 80-EG	TiN20-EG	TiN50-EG
		ρ kg m ⁻³	ρ kg m ⁻³	ρ kg m ⁻³	ρ kg m ⁻³	ρ kg m ⁻³	ρ kg m ⁻³
288.15	0.000	1116.6	1116.6	1116.6	1116.6	1116.6	1116.6
288.15	0.010	1123.9	1124.5	1120.6	1120.9	1124.7	1125.0
288.15	0.025	1131.0	1131.4	1130.4	1131.1	1137.2	1138.0
288.15	0.050	1149.7	1151.0	1143.4	1143.7	1159.8	1159.9
298.15	0.000	1109.7	1109.7	1109.7	1109.7	1109.7	1109.7
298.15	0.010	1116.9	1117.2	1113.9	1113.6	1118.0	1118.1
298.15	0.025	1124.1	1124.6	1123.7	1124.2	1130.3	1131.0
298.15	0.050	1142.8	1143.6	1138.2	1138.7	1152.8	1152.8
308.15	0.000	1102.7	1102.7	1102.7	1102.7	1102.7	1102.7
308.15	0.010	1108.8	1109.5	1106.8	1107.5	1111.0	1111.0
308.15	0.025	1117.1	1117.6	1117.3	1117.5	1123.2	1123.9
308.15	0.050	1135.8	1135.8	1131.7	1132.3	1145.6	1145.6

$$c_{p,nf} = (1 - \varphi_m) c_{p,bf} + \varphi_m c_{p,p}.$$

Table 4

Experimental values of isobaric heat capacity of ethylene glycol based nanofluids containing various types of nitride nanoparticles at various fractions and temperatures.

T_{set} K	φ_m –	AlN20-EG		AlN50-EG		Si ₃ N ₄ 20-EG		Si ₃ N ₄ 80-EG		TiN20-EG		TiN50-EG	
		T K	c_p J g ⁻¹ K ⁻¹	T K	c_p J g ⁻¹ K ⁻¹	T K	c_p J g ⁻¹ K ⁻¹	T K	c_p J g ⁻¹ K ⁻¹	T K	c_p J g ⁻¹ K ⁻¹	T K	c_p J g ⁻¹ K ⁻¹
288.15	0.000	288.41	2.400	288.41	2.400	288.41	2.400	288.41	2.400	288.41	2.400	288.41	2.400
288.15	0.010	288.46	2.359	288.44	2.383	288.43	2.362	287.76	2.365	288.46	2.364	288.44	2.389
288.15	0.025	287.75	2.326	288.46	2.347	288.43	2.302	287.75	2.327	287.75	2.320	288.46	2.357
288.15	0.050	287.75	2.283	288.47	2.293	288.43	2.233	287.76	2.255	287.75	2.267	288.47	2.287
288.15	0.100	288.46	2.216	287.75	2.237	288.43	2.172	287.76	2.186	288.46	2.206	287.75	2.215
298.15	0.000	298.40	2.459	298.40	2.459	298.40	2.459	298.40	2.459	298.40	2.459	298.40	2.459
298.15	0.010	297.75	2.411	297.75	2.430	297.77	2.422	298.42	2.437	297.75	2.424	297.75	2.438
298.15	0.025	298.44	2.370	297.76	2.405	297.76	2.363	298.42	2.399	298.44	2.379	297.76	2.402
298.15	0.050	298.44	2.329	297.76	2.339	297.77	2.301	298.41	2.327	298.44	2.324	297.76	2.334
298.15	0.100	297.76	2.271	298.44	2.280	297.77	2.232	298.42	2.257	297.76	2.251	298.44	2.265
308.15	0.000	308.39	2.516	308.39	2.516	308.39	2.516	308.39	2.516	308.39	2.516	308.39	2.516
308.15	0.010	308.43	2.469	307.76	2.490	308.40	2.480	307.77	2.482	308.43	2.477	307.76	2.491
308.15	0.025	308.43	2.428	308.43	2.451	308.41	2.413	307.77	2.444	308.43	2.428	308.43	2.464
308.15	0.050	307.76	2.389	308.43	2.395	308.40	2.347	307.77	2.366	307.76	2.371	308.43	2.390
308.15	0.100	308.42	2.331	307.76	2.344	308.41	2.289	307.77	2.303	308.42	2.309	307.76	2.317

Article

Computational Study of Flow and Heat Transfer Characteristics of EG-Si₃N₄ Nanofluid in Laminar Flow in a Pipe in Forced Convection Regime [†]

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[†] This paper is an extended version of our paper published in the 1st International Conference on Nanofluids (ICNf) and 2nd European Symposium on Nanofluids (ESNf), 26–28 June 2019, Castelló, Spain. Conference Proceedings, pp. 226–230.

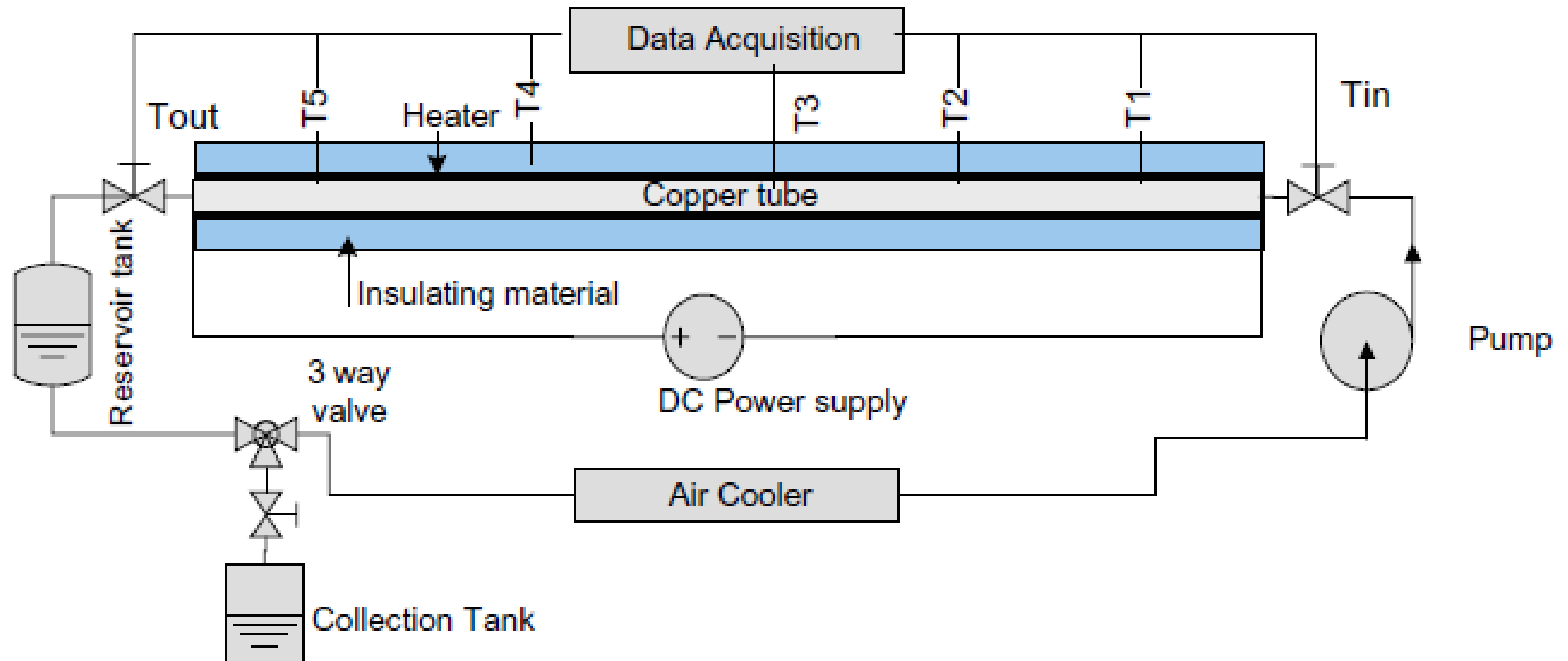
Received: 12 November 2019; Accepted: 9 December 2019; Published: 22 December 2019



Abstract: Laminar flow of ethylene glycol-based silicon nitride (EG-Si₃N₄) nanofluid in a smooth horizontal pipe subjected to forced heat convection with constant wall heat flux is computationally modeled and analyzed. Heat transfer is evaluated in terms of Nusselt number (Nu) and heat transfer coefficient for various volume fractions of Si₃N₄ nanoparticles in the base fluid and different laminar flow rates. The thermophysical properties of the EG-Si₃N₄ nanofluid are taken from a recently published experimental study. Computational modelling and simulation are performed using open-source software utilizing finite volume numerical methodology. The nanofluid exhibits non-Newtonian rheology and it is modelled as a homogeneous single-phase mixture, the properties of which are determined by the nanoparticle volume fraction. The existing features of the software to simulate single-phase flow are extended by implementing the energy transport coupled to the fluid flow and the interaction of the fluid flow with the surrounding pipe wall via the applied wall heat flux. In addition, the functional dependencies of the thermophysical properties of the nanofluid on the volume fraction of nanoparticles are implemented in the software, while the non-Newtonian rheological behavior of the nanofluid under consideration is also taken into account. The obtained results from the numerical simulations show very good predicting capabilities of the implemented computational model for the laminar flow coupled to the forced convection heat transfer. Moreover, the analysis of the computational results for the nanofluid reflects the increase of heat transfer of the EG-Si₃N₄ nanofluid in comparison to the EG for all the considered nanoparticle volume fractions and flow rates, indicating promising features of this nanofluid in heat transfer applications.

Keywords: EG-Si₃N₄ nanofluid; numerical simulation; laminar flow; heat transfer coefficient

Wen D, Ding Y. (2004) **Experimental investigation into convective heat transfer of nanofluids at the entrance region under laminar flow conditions**, International Journal of Heat and Mass Transfer, 47:5181-5188.



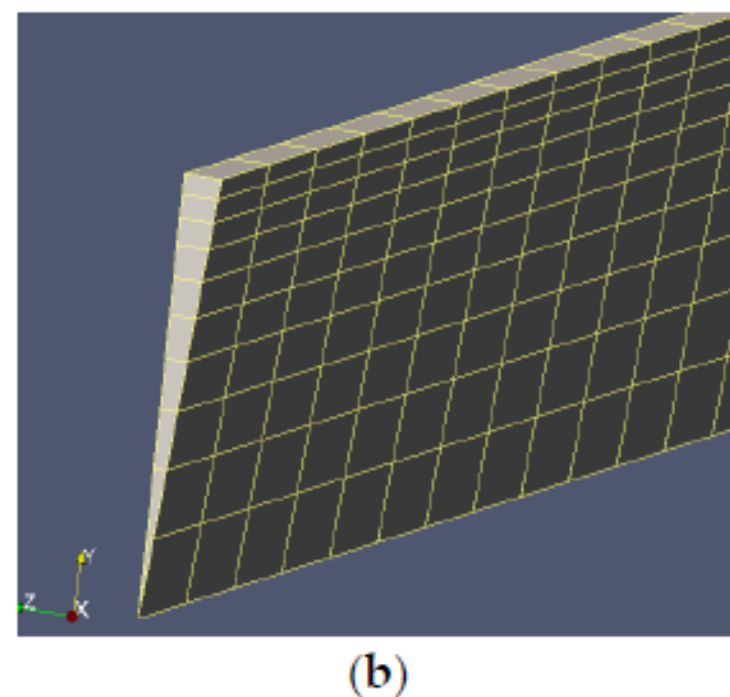
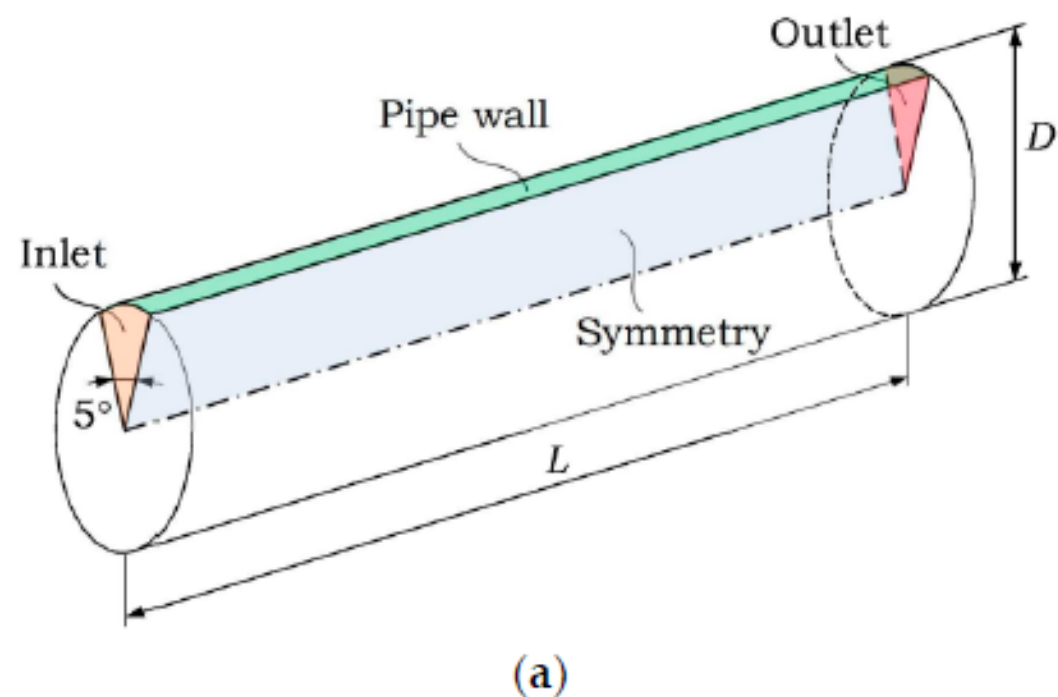


Figure 2. Geometry and mesh modeling: (a) 2-D axisymmetric domain flow; (b) Snapshot of the 2-D numerical mesh.

Table 2. Parameters used for the simulation scenarios for ethylene glycol-based silicon nitride (EG-Si₃N₄) nanofluid.

Pipe Diameter D	Pipe Length L	Inlet Temperature T_{in}	Wall Heat Flux q	Volume Flow Rate Q	Nanoparticle Volume Fraction φ_v
4 mm	2 m	293 K	10 kW/m ²	8×10^{-6} – 8.4×10^{-5} m ³ /s	0–0.035

Momentum:

- inlet: $\mathbf{U} = (U_{in}, 0, 0), \nabla p = 0,$
- pipe wall: $\mathbf{U} = (0, 0, 0), \nabla p = 0,$
- outlet: $\nabla \mathbf{U} = 0, p = p_{out}.$

Energy:

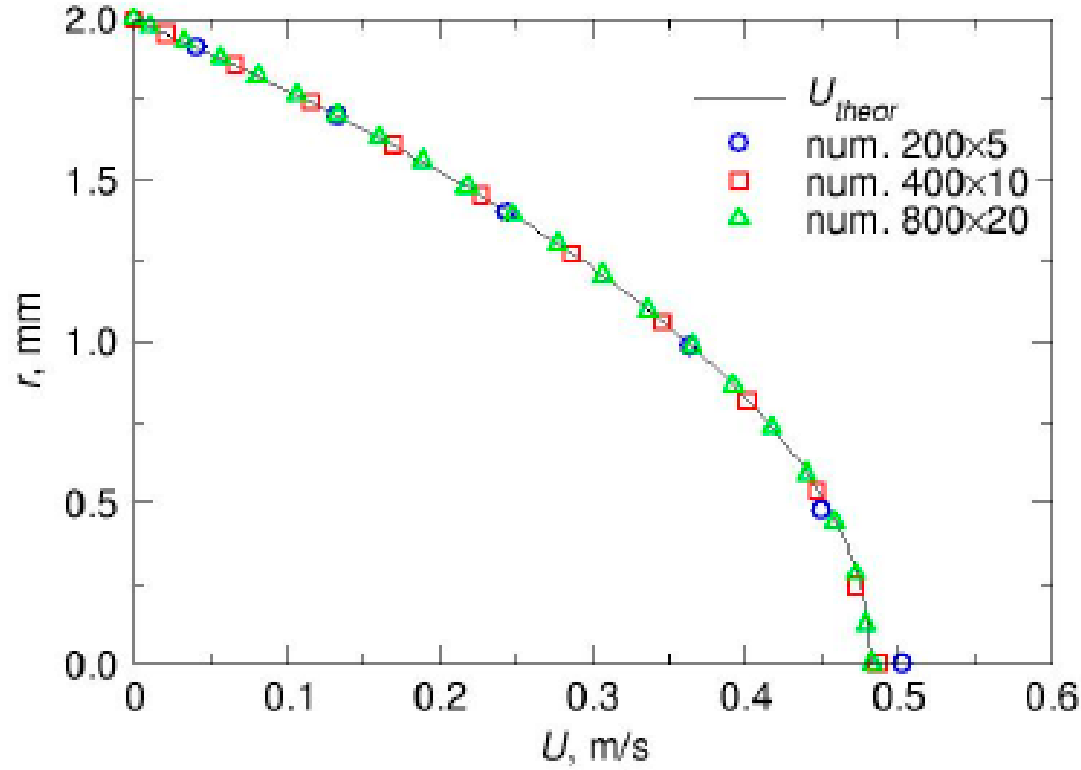
- inlet: $T = T_{in},$
- pipe wall: $\nabla T = q/k,$ where q is the applied wall heat flux,
- outlet: $\nabla T = qD\pi/(\dot{m}c_p),$

$$\nabla \cdot (\rho \mathbf{U}) = 0, \tag{1}$$

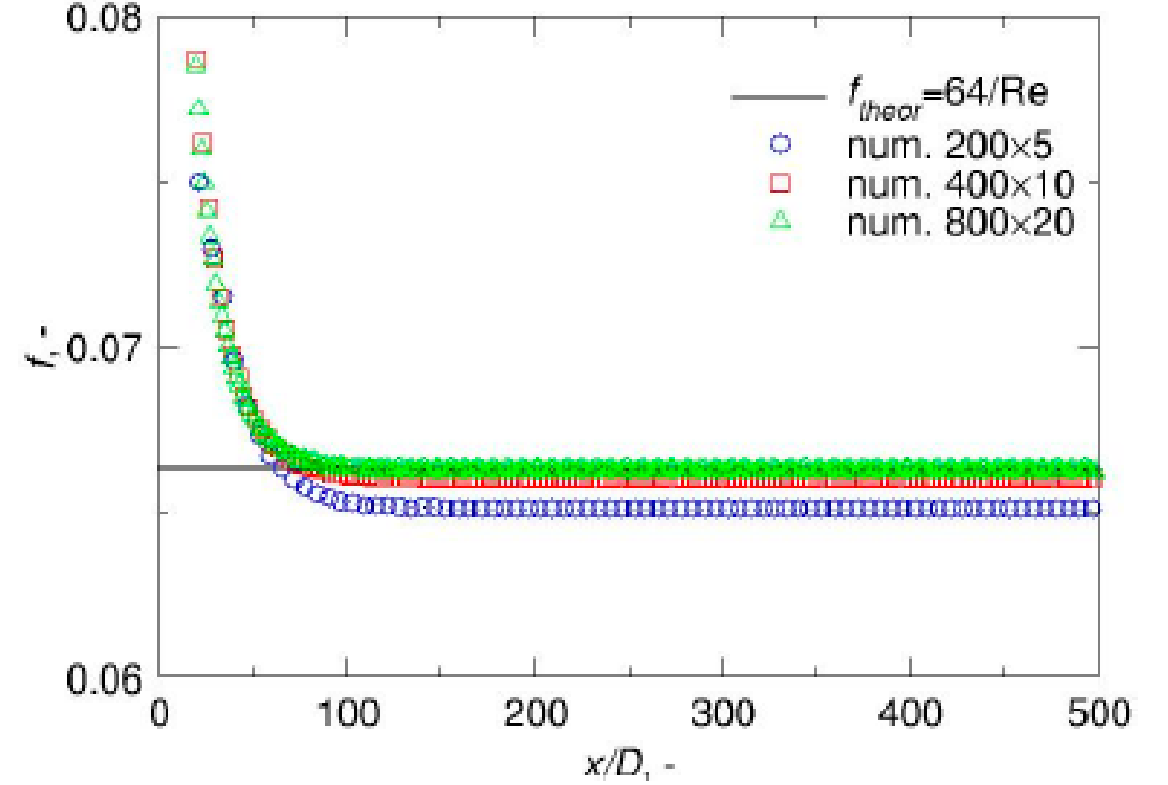
$$\nabla \cdot (\rho \mathbf{U} \mathbf{U}) = -\nabla p + \nabla \cdot \boldsymbol{\tau}, \tag{2}$$

$$\nabla \cdot (\rho c_p \mathbf{U} T) = \nabla \cdot (k \nabla T), \tag{3}$$

$$f = \frac{-2\nabla p D}{\rho \bar{v}^2}$$



(a)

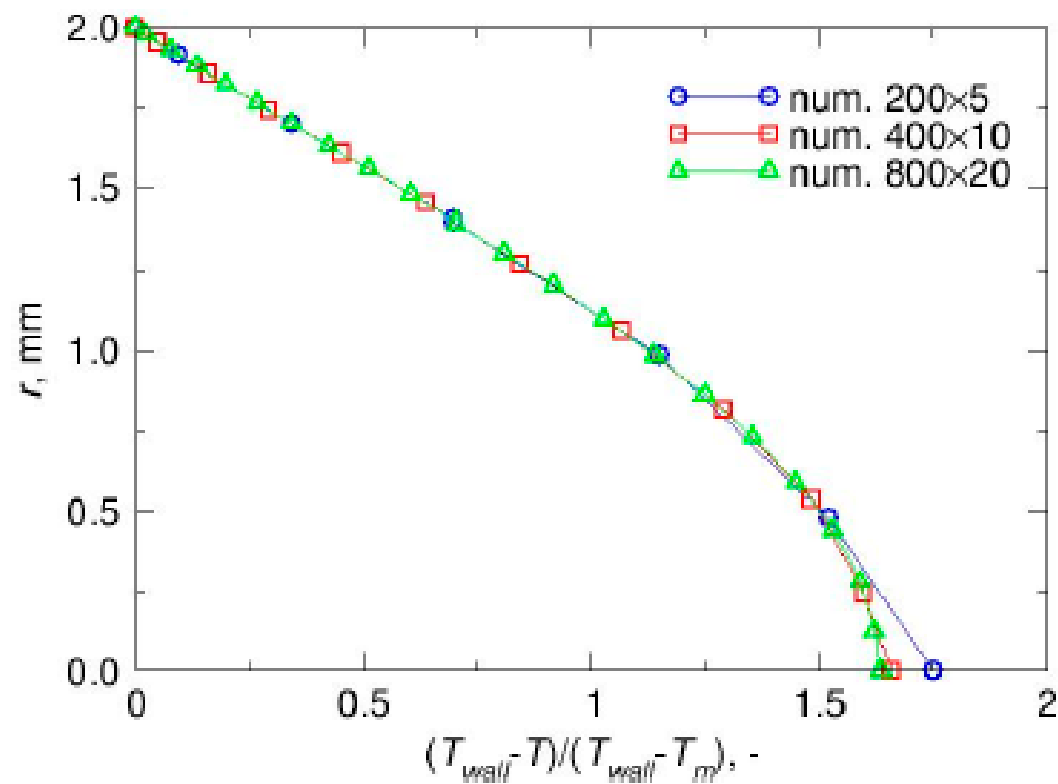


(b)

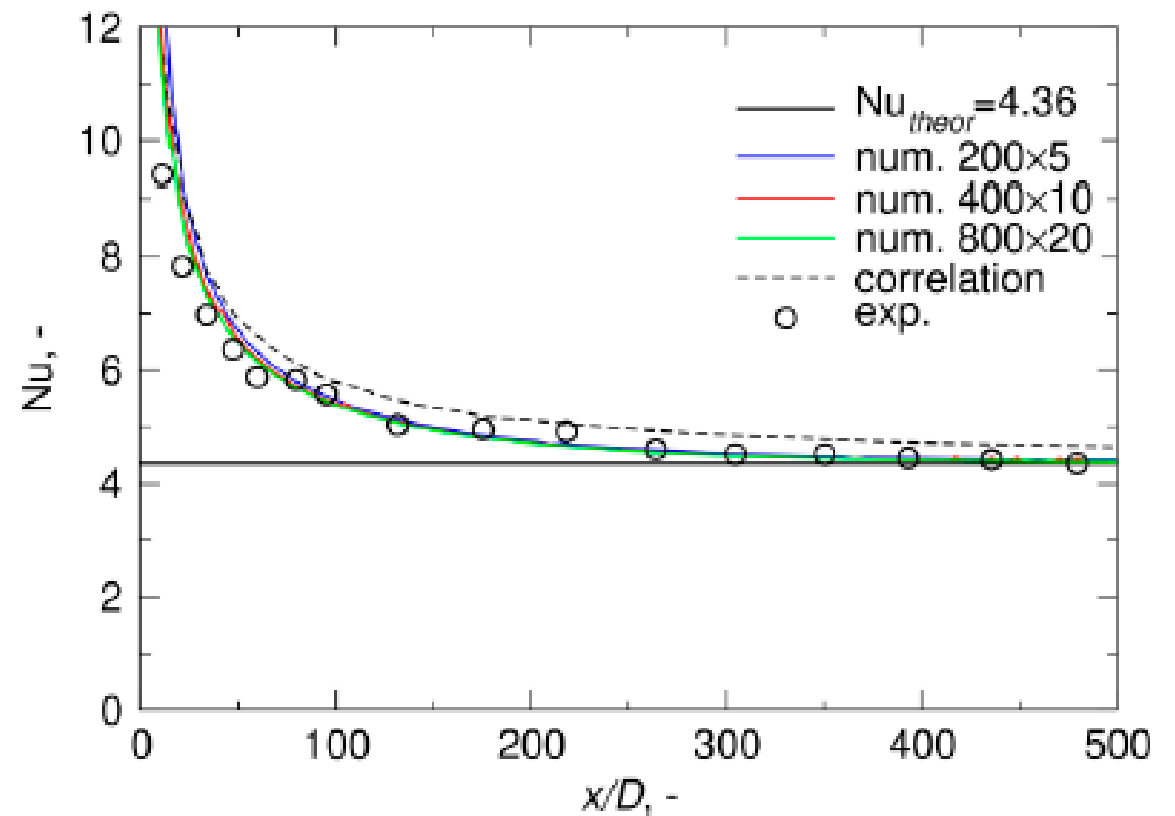
Figure 3. Results for laminar flow of water at $Re = 965$: (a) The computed velocity profile evaluated at $x/D = 625$; (b) The computed friction factor.

$$T_m = \frac{\int_S \rho c_p T \mathbf{U} \cdot d\mathbf{S}}{\int_S \rho c_p \mathbf{U} \cdot d\mathbf{S}},$$

$$h = \frac{-k \nabla T_{wall}}{T_{wall} - T_m}, \quad Nu = \frac{hD}{k},$$

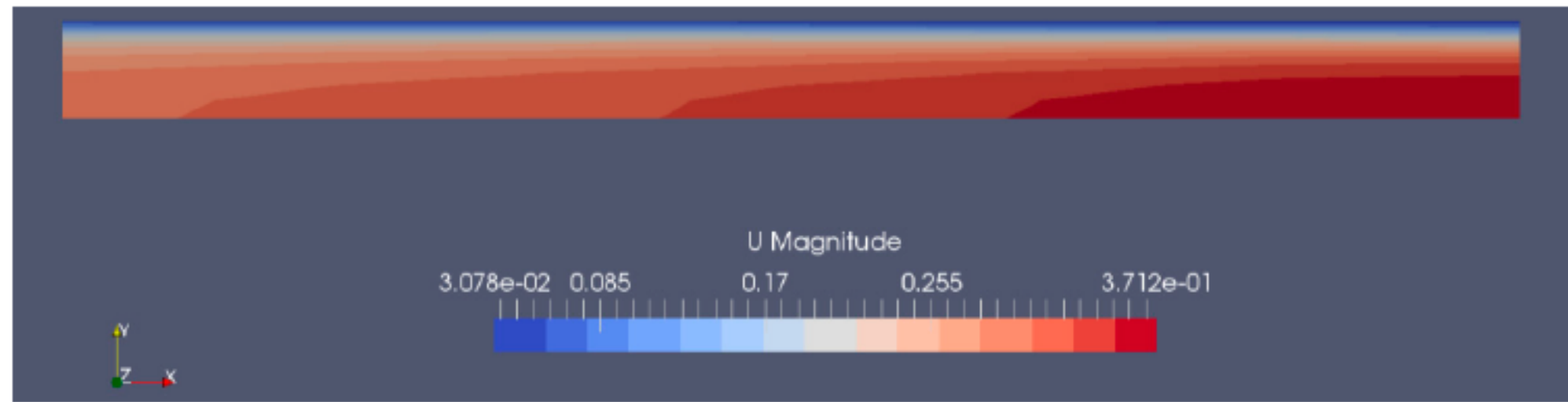


(a)

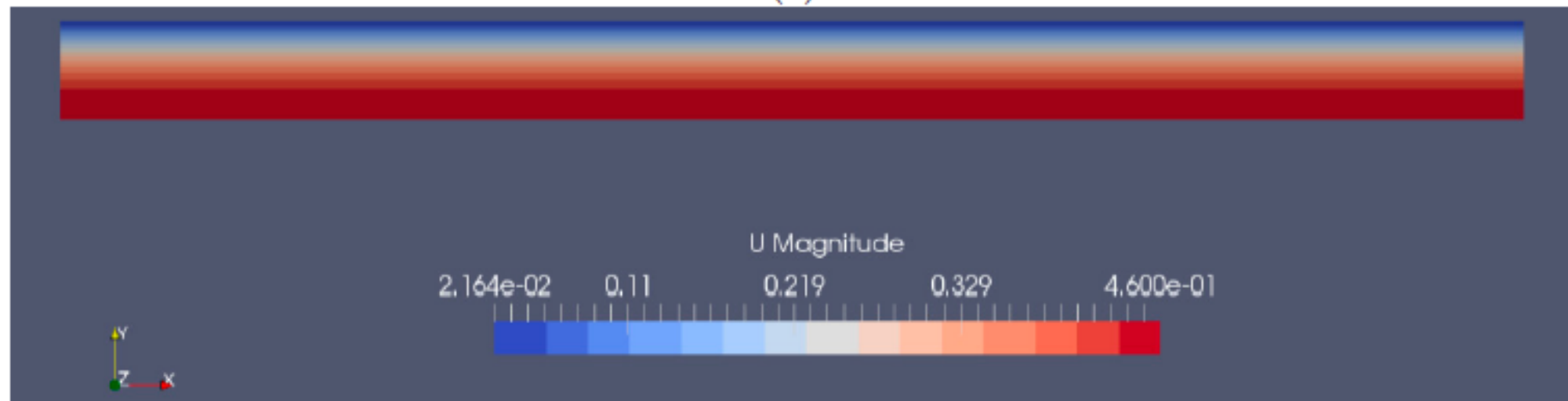


(b)

Figure 4. Results for laminar flow of water at $Re = 965$: (a) The computed dimensionless temperature profile evaluated at $x/D = 625$; (b) The computed Nusselt number.

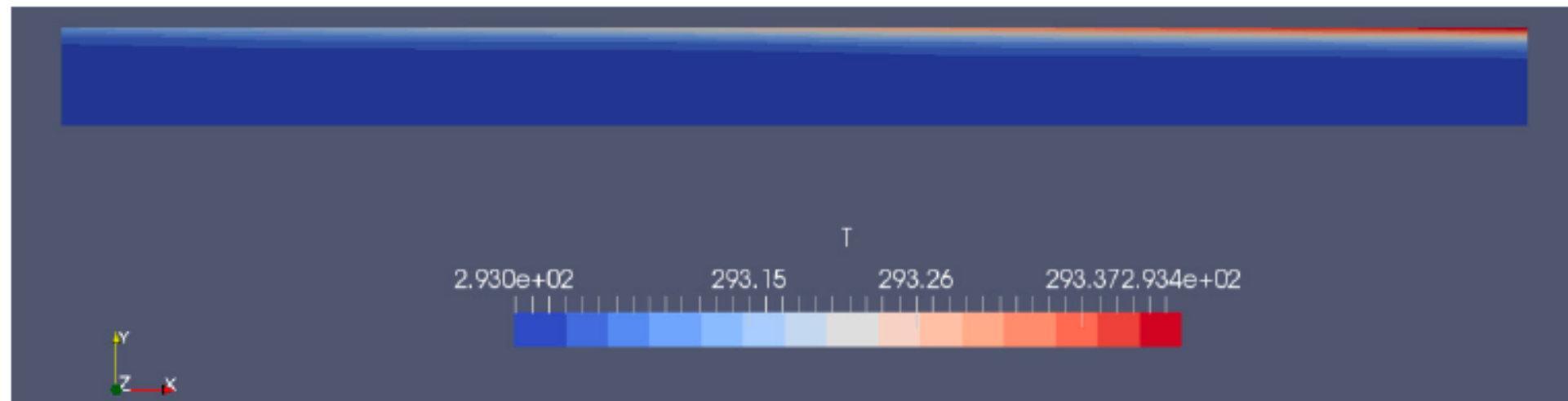


(a)

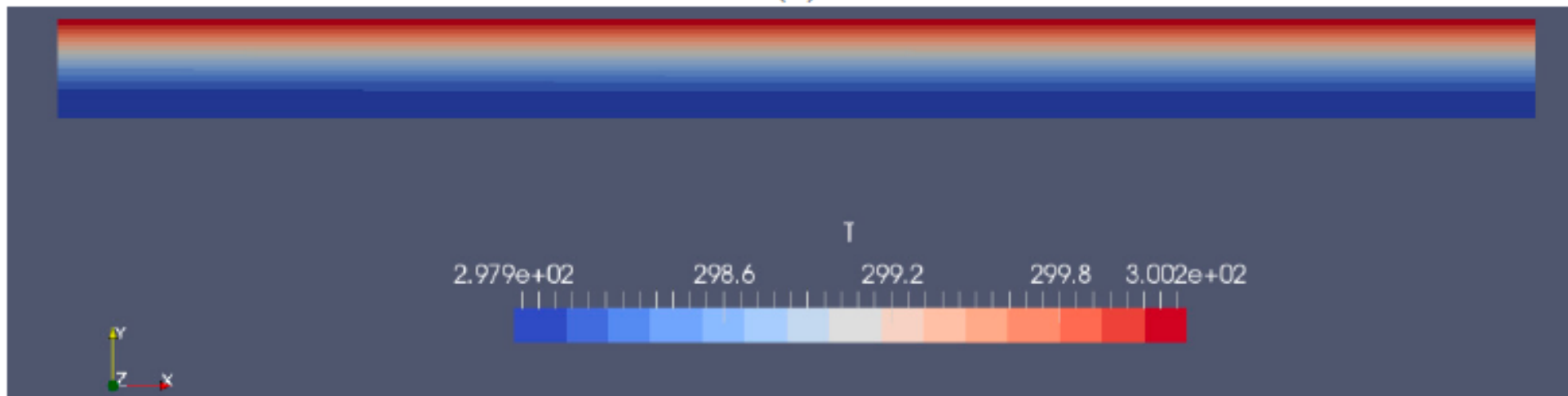


(b)

Figure 5. The computed velocity distribution (expressed in m/s) for laminar flow of water at $Re = 965$: (a) Inlet part of the pipe; (b) Outlet part of the pipe.



(a)



(b)

Figure 6. The computed temperature distribution (expressed in K) for laminar flow of water at $Re = 965$: (a) Inlet part of the pipe; (b) Outlet part of the pipe.

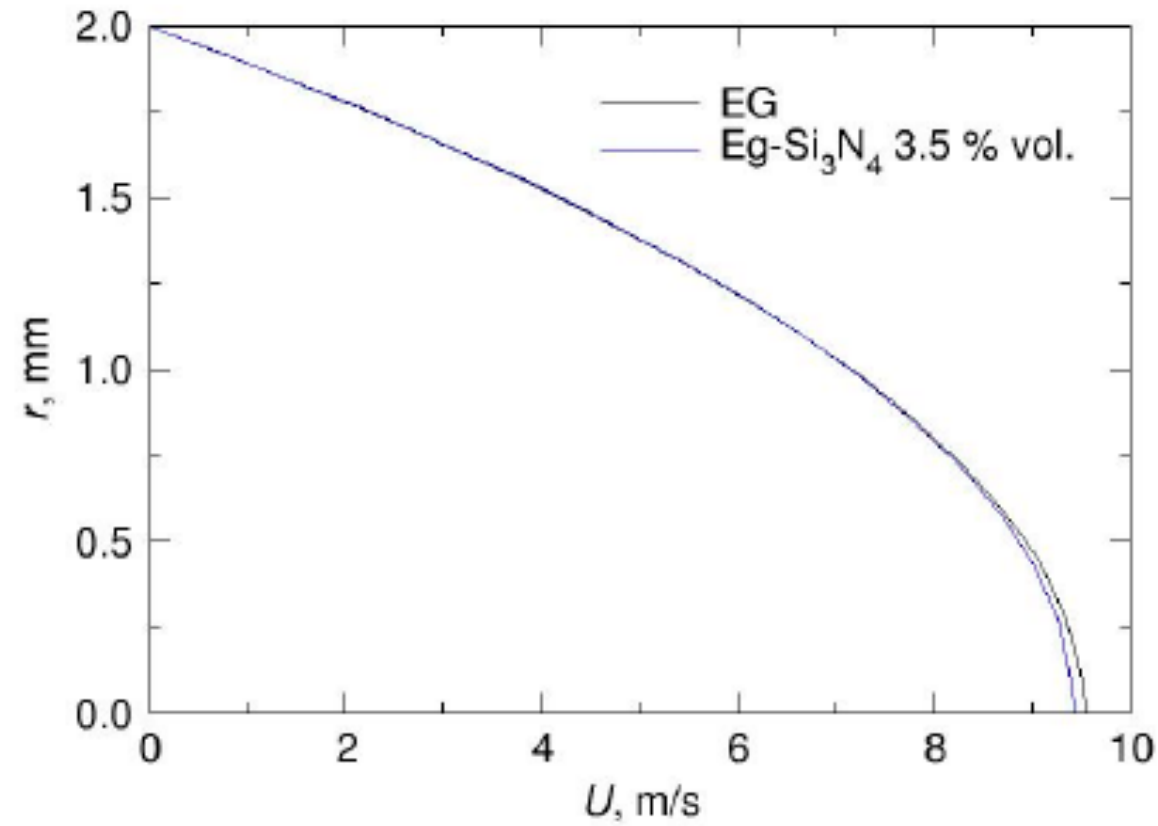
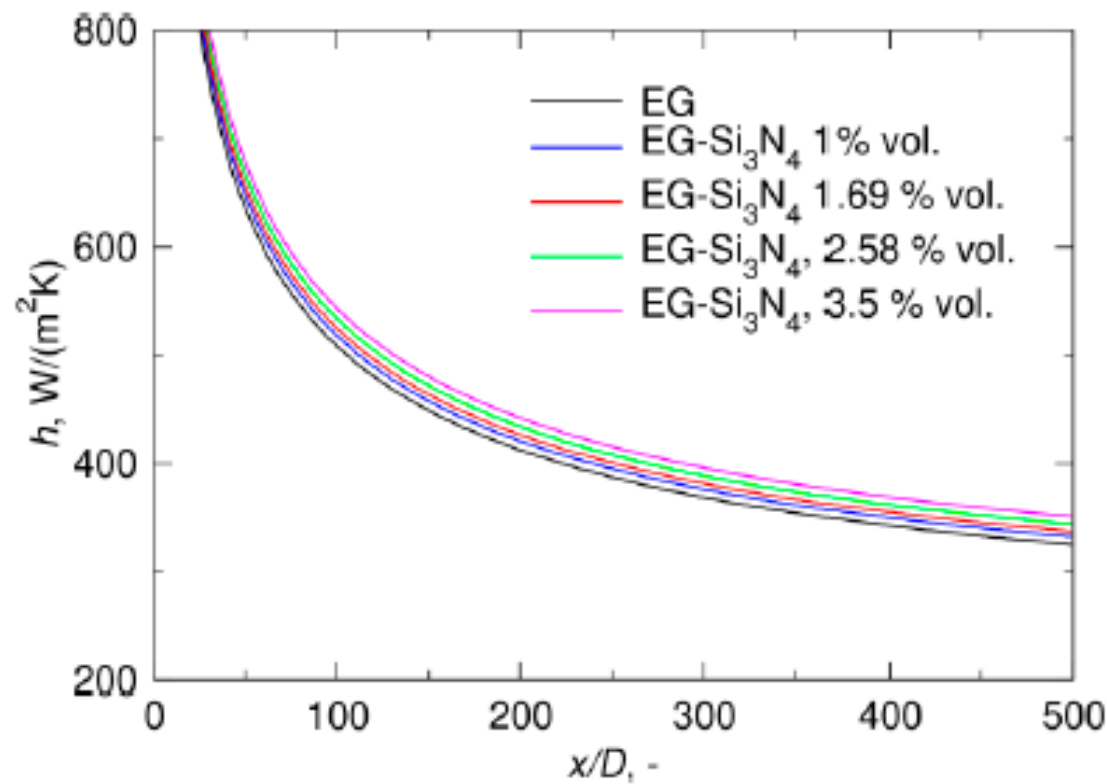
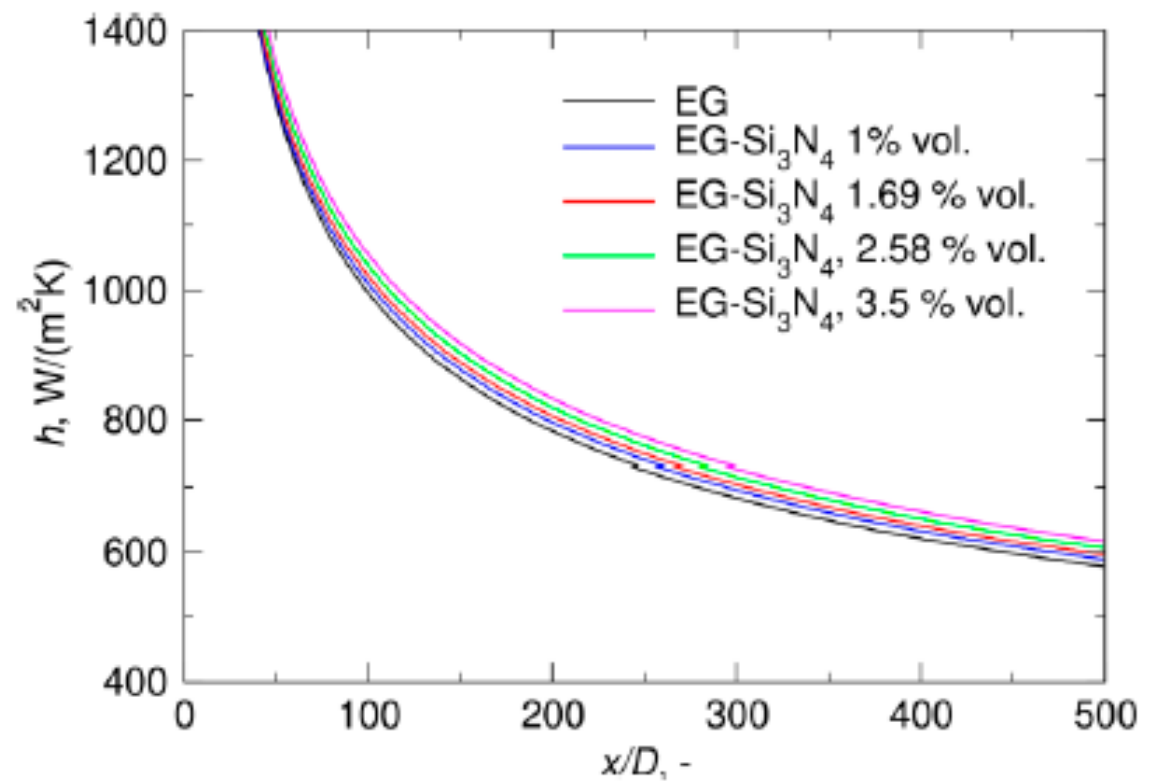


Figure 7. The computed velocity profile for laminar flow of pure EG and of EG-Si₃N₄ nanofluid with the nanoparticle volume fraction of 3.5% at $Q = 6 \times 10^{-5} \text{ m}^3/\text{s}$, which corresponds to $Re = 1500$ for pure EG.



(a)



(b)

Figure 8. Computational results for laminar flow of EG-Si₃N₄ nanofluid with various nanoparticle volume fractions and the imposed wall heat flux $q = 10 \text{ kW/m}^2$: (a) Heat transfer coefficient at the volume flow rate of $Q = 8 \times 10^{-6} \text{ m}^3/\text{s}$, which corresponds to $Re = 200$ for pure EG; (b) Heat transfer coefficient at a volume flow rate of $Q = 6 \times 10^{-5} \text{ m}^3/\text{s}$, which corresponds to $Re = 1500$ for pure EG.

$$\bar{h} = \frac{1}{L} \int_0^L h dx$$

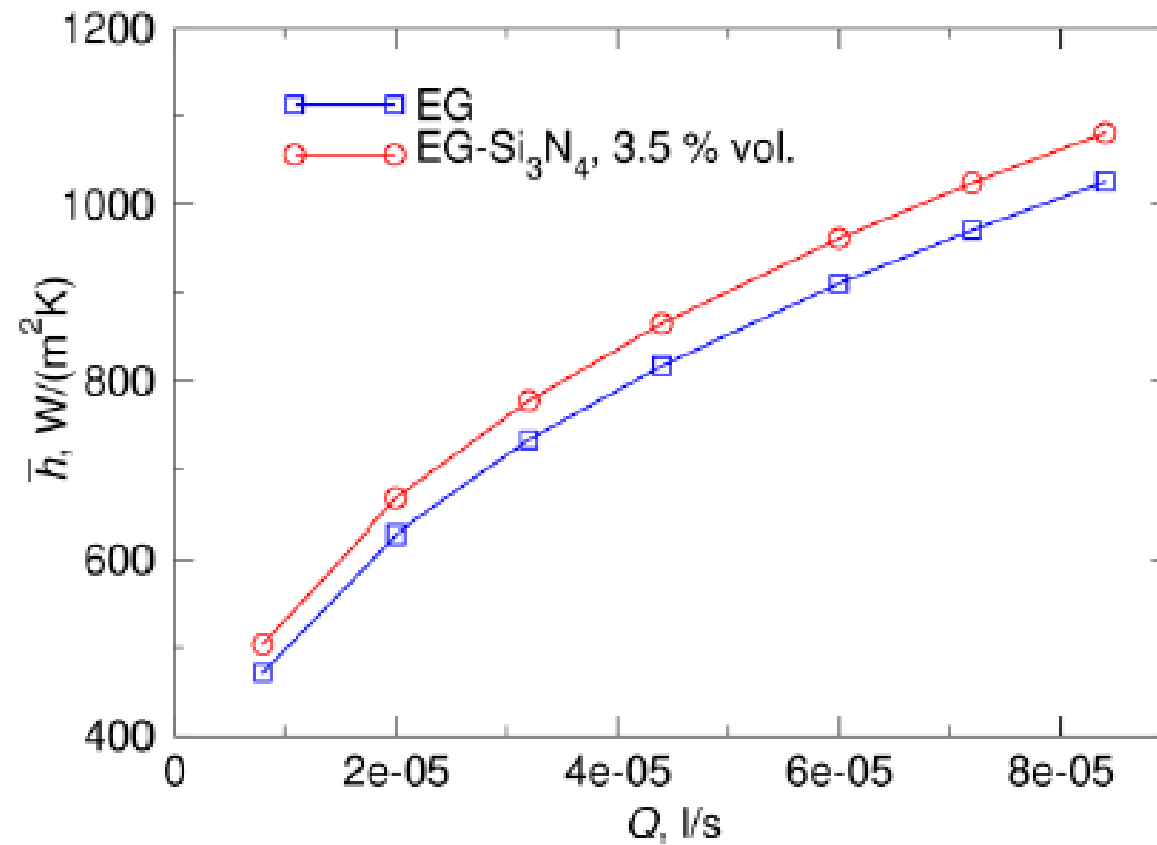


Figure 9. Computational results for the enhancement of the heat transfer coefficient for the EG-Si₃N₄ nanofluid at the nanoparticle volume fraction of 3.5% over a range of nanofluid volume flow rates corresponding to Re between 200 and 2100 for pure EG.

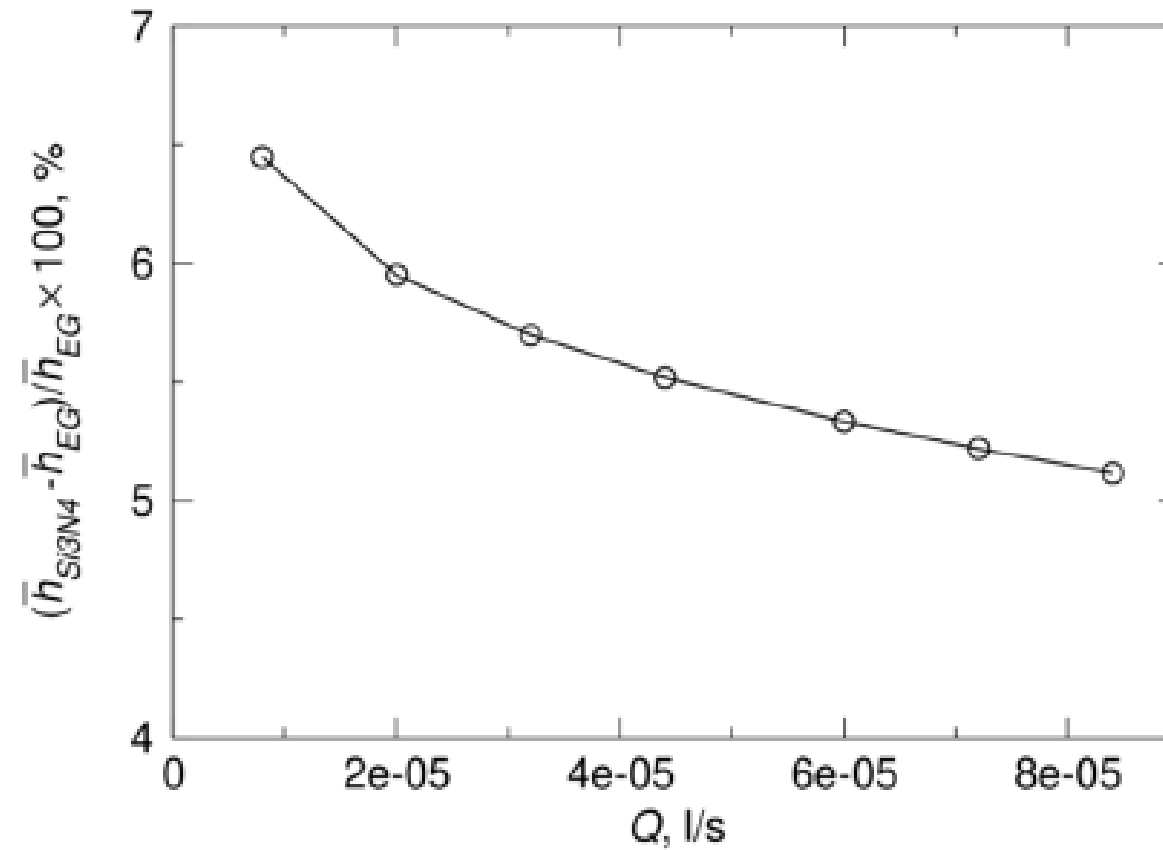


Figure 10. Computational results for the relative enhancement of the heat transfer coefficient for the EG-Si₃N₄ nanofluid at the nanoparticle volume fraction of 3.5% over a range of nanofluid volume flow rates corresponding to Re between 200 and 2100 for pure EG.

$$\frac{k_{nf}}{k_{bf}} > \left(\frac{\mu_{nf}}{\mu_{bf}} \right)^{1/3},$$

Table 5. Performance evaluation of the EG-Si₃N₄ nanofluid.

Nanoparticle Volume Fraction φ_v	Thermal Conductivity Ratio k_{nf}/k_{bf}	Viscosity Ratio $(\mu_{nf}/\mu_{bf})^{1/3}$
0.0	1	1
0.0033	1.00947	1.04483
0.0066	1.01894	1.05741
0.01	1.02870	1.07655
0.0134	1.03846	1.11588
0.0169	1.04850	1.13608
0.0258	1.07404	1.24519
0.035	1.100450	1.44602



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Numerical Analysis of Heat Transfer Performances of Ionic Liquid and Ionanofluids with Temperature-Dependent Thermophysical Properties

by Amra Hasečić ^{1,*} , Jaber Hmoud Almutairi ² , Siniša Bikić ³ and Ejub Džaferović ¹

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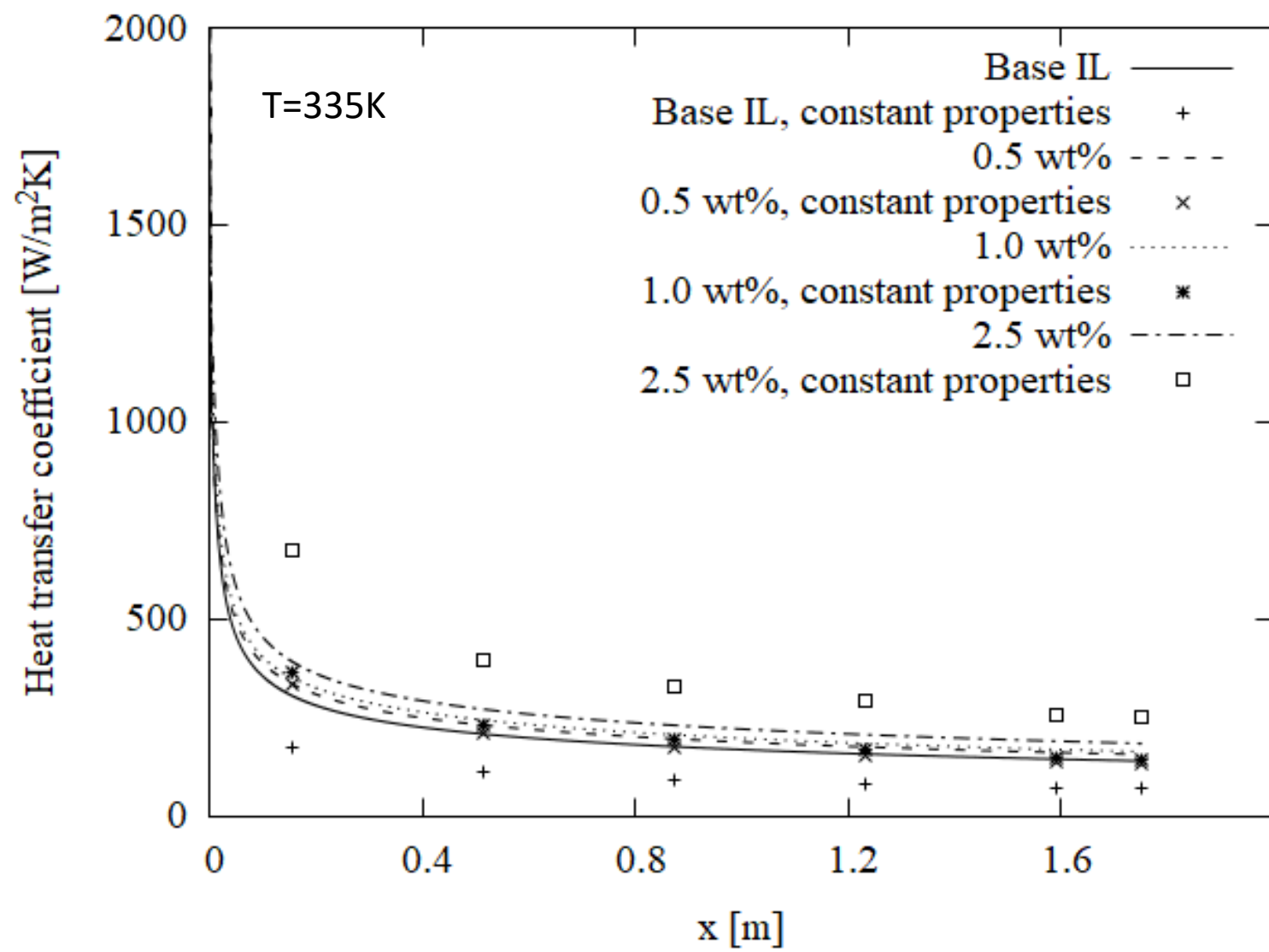
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Experimental investigation on thermophysical properties of iobiofluids

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Abstract

The aim of this research was to investigate the density, thermal conductivity, and viscosity of dispersions of agricultural biomass particles in ionic liquid [HMIM][NTf₂] used as a base fluid. This research is a continuation of the development of IoBioFluids, a new class of dispersions obtained by suspending particles produced from agricultural biomass, as a sustainable alternative to IoNanoFluids. Dispersions with different mass concentration of particles (0, 0.5, 1, 2.5, and 5 wt%) were studied at different temperatures (20°C, 30°C, 40°C, and 50°C). Agricultural biomass, namely sunflower stalks, was used for particle production. The dispersion was prepared by applying the commonly used two-step method. In the first step, particles were produced as dry powder from hydrothermal carbonization and heat treatment in the inert atmosphere oven. In the second step, the particles were dispersed into ionic liquid. A rheological investigation showed that dispersions exhibited Newtonian behavior for shear rates over 10 s⁻¹. Density, thermal conductivity, and dynamic viscosity of dispersions increased with greater mass concentration of particles. Two applied merit

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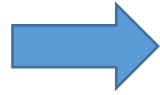


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Suncokret



Čestice



Disperzija

260 °C, 10 hours, 80 bar
Reaktor sa kontrolom pritiska azota

< 63 mm



1

Maseni odnos



20



limusnka kiselina 1%



Mlin za sečenje



Ciklonski mlin



Vlažna biočađ

Filtriranje vodom



SSW70 (VIMS Elektrik, Serbia)
60 °C , 20 hours



Biočad



Boks i keramičke posude



PŽ-A (VIMS Elektrik, Serbia)
900°C, 1 hour



Čestice



Vorteks (IKA, Germany)
10 min



Ultrazvučno kupatilo,
model Elmasonic P (Elma, Germany)
45 min, 37 kHz



Ultrazvučna sonda Sonoplus mini 20
(Badelin, Germany)
45 min, 75% Amplitude



Introduction



JSM - 6460LV (JEOL, Japan)

EDS model INCA (Oxford Instruments, UK)



Malvern Zetasizer Nano ZS (Malvern Panalytical, UK)

Introduction

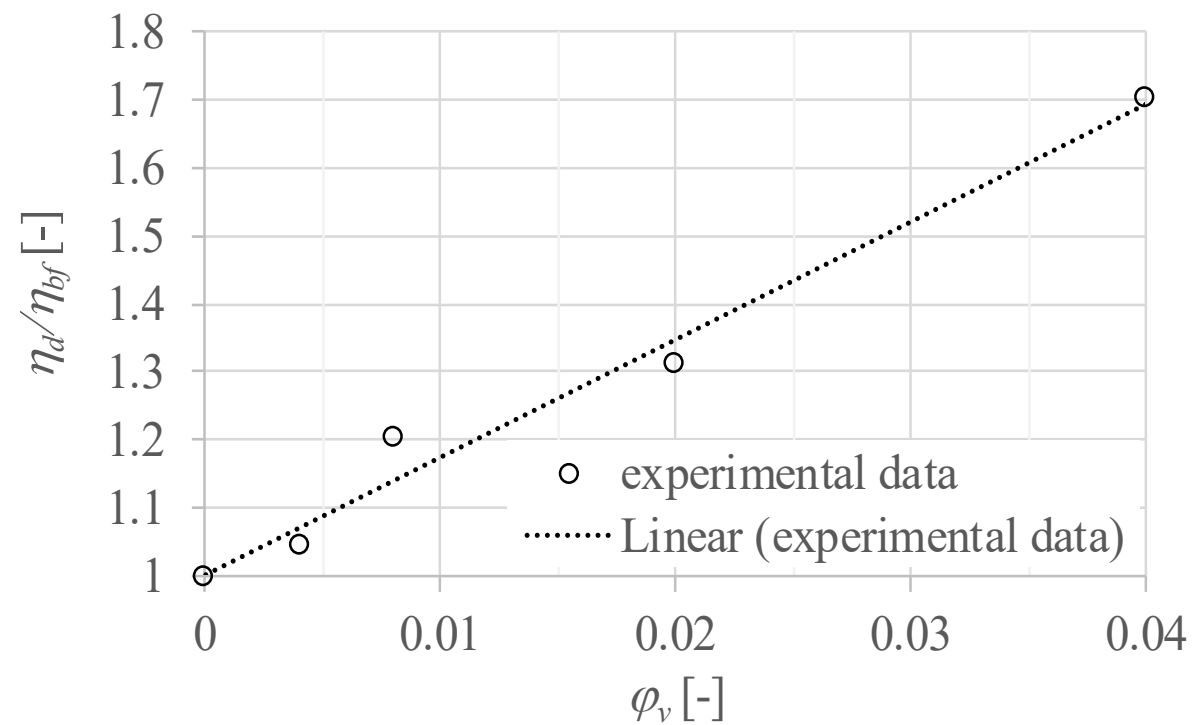
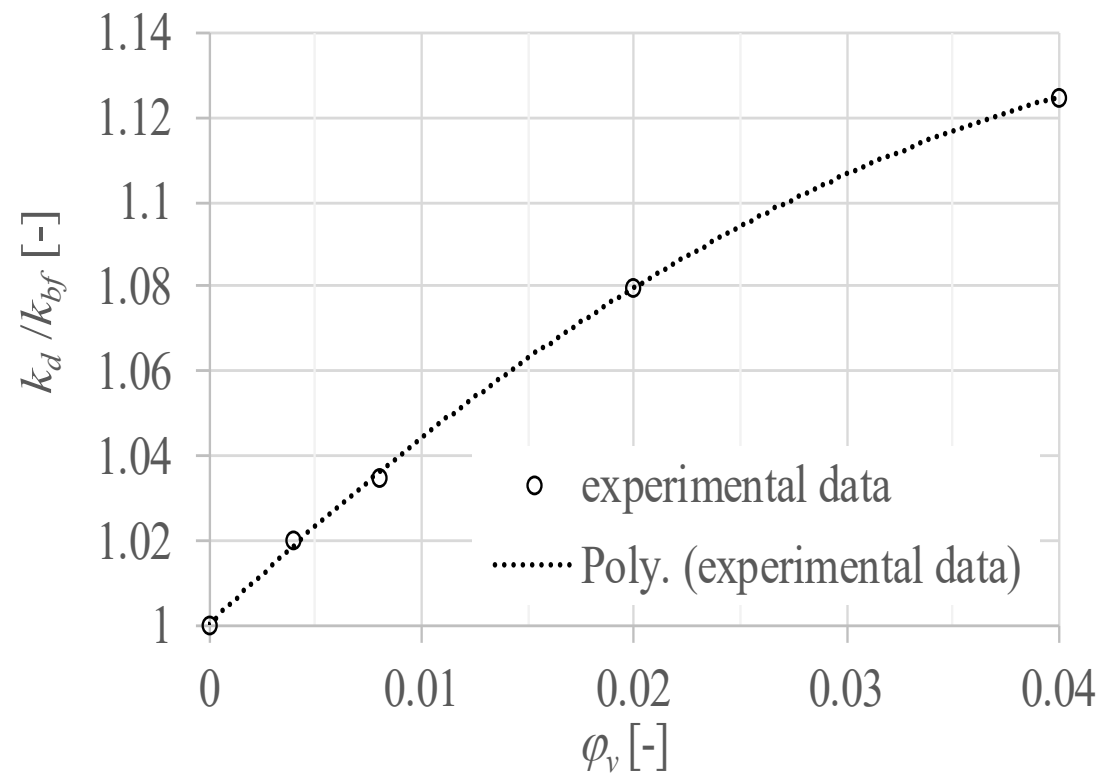
Termokupatilo WCH-30 (WITEG, Germany)



Meter Tempos (Meter Environment, USA)



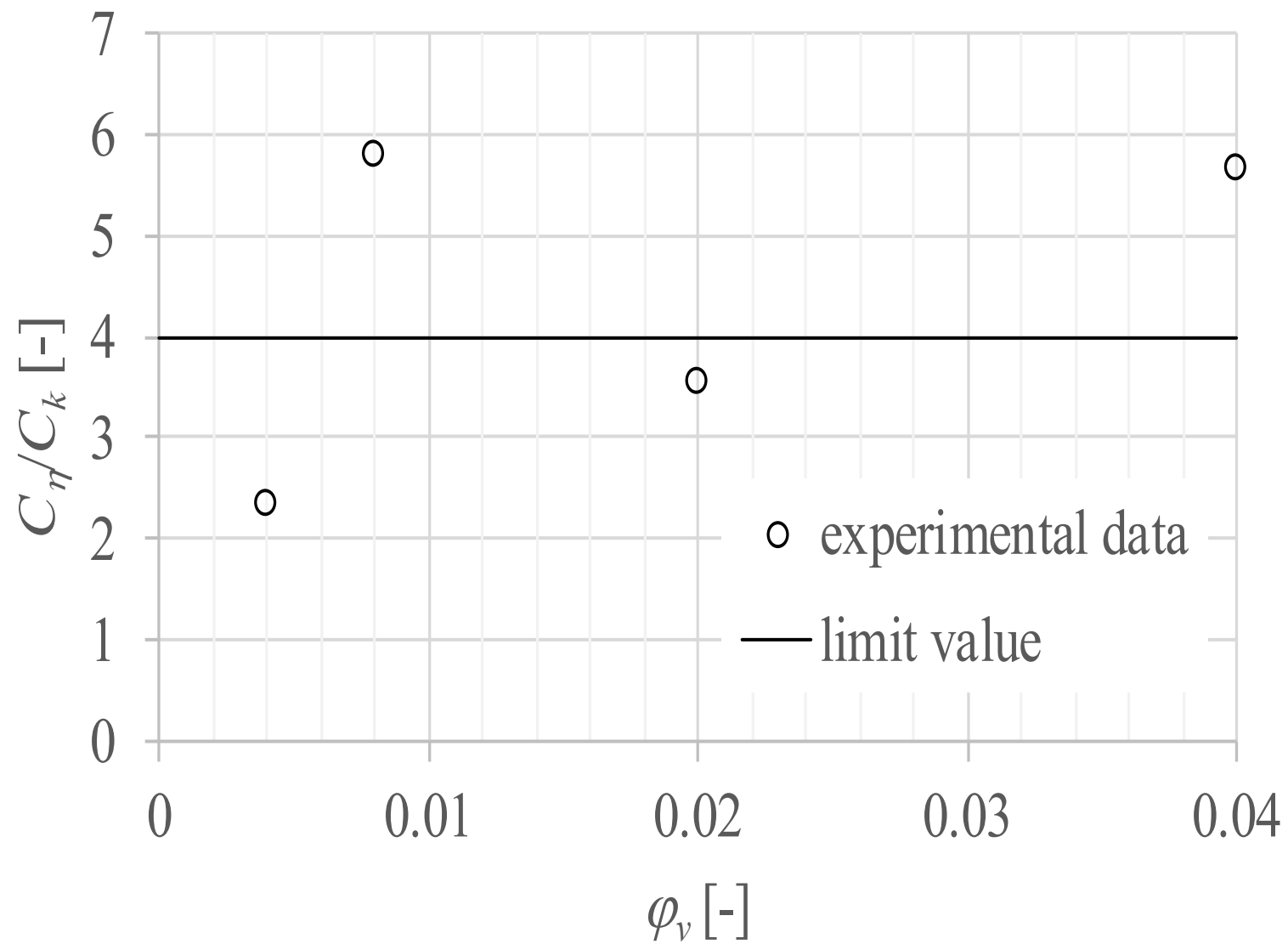
Viskozimetar V2-R (TQC, Netherland)



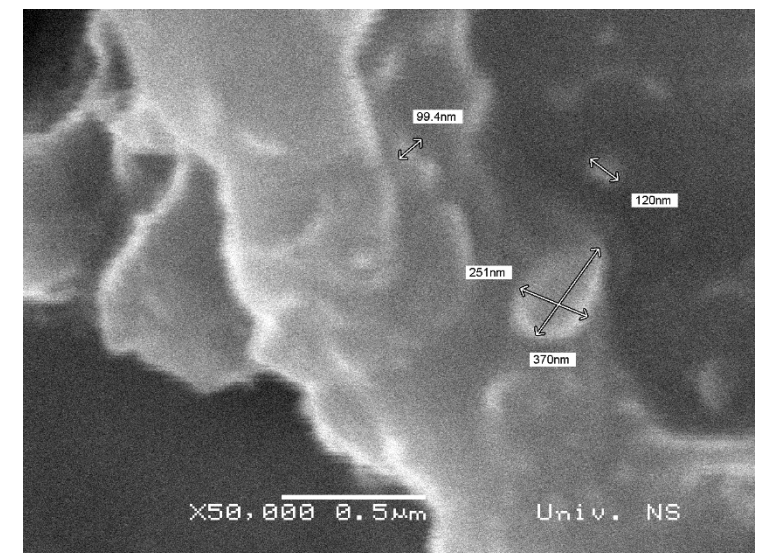
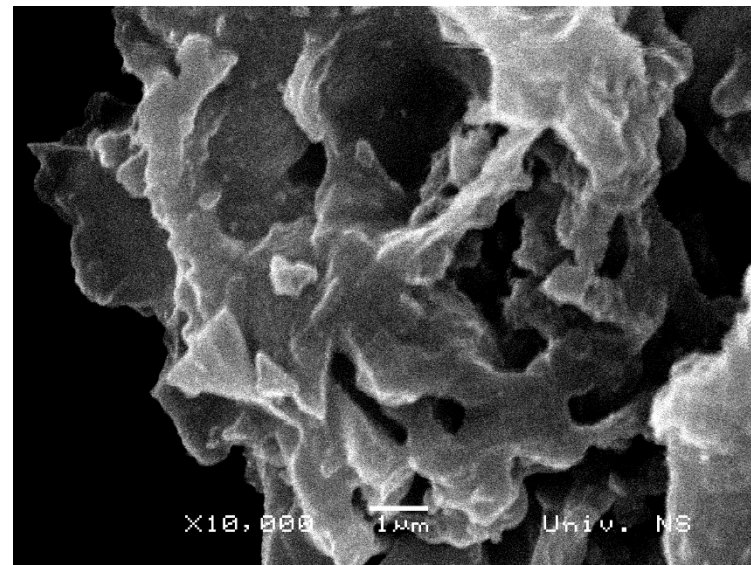
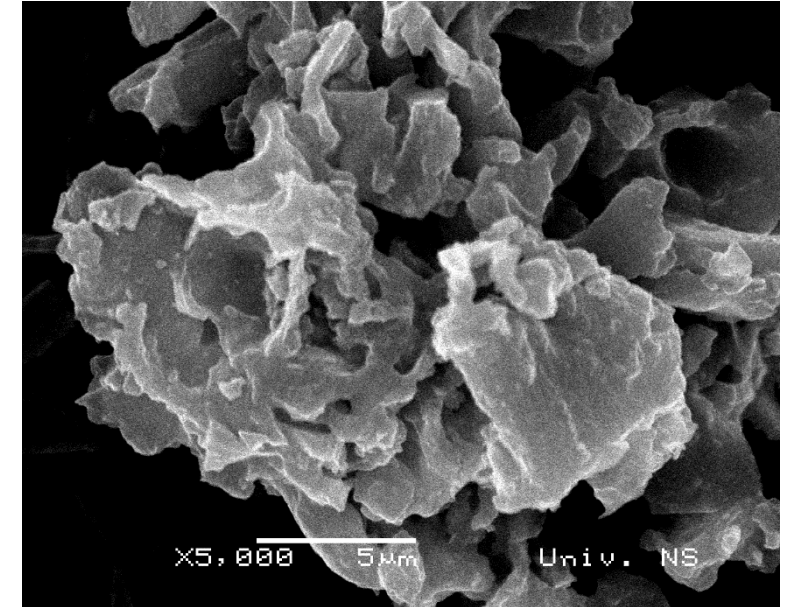
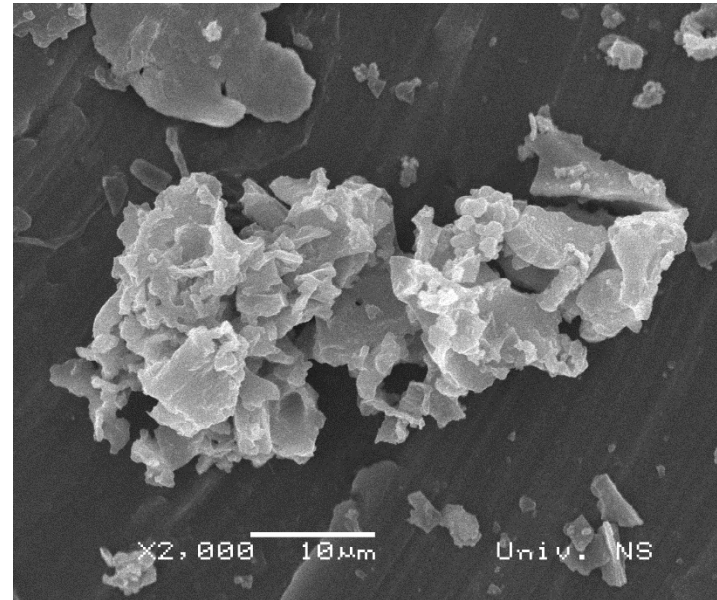
$$\frac{\eta_d}{\eta_{bf}} = 1 + 17.363 \cdot \varphi_v$$

$$\frac{k_d}{k_{bf}} = 1 + 3.3396 \cdot \varphi_v$$

$$\frac{C_\mu}{C_k} < 4$$



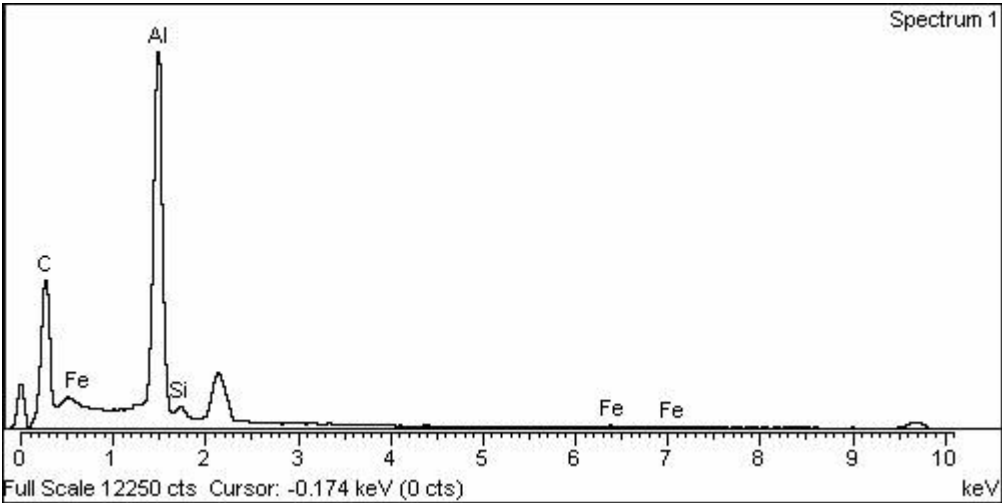
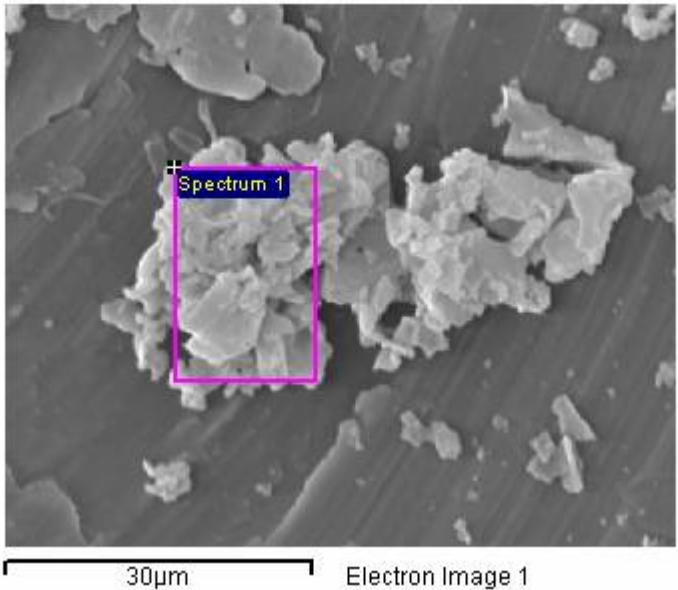
SEM



Rezultati energetske-disperzivne rendgenske spektroskopije čestica

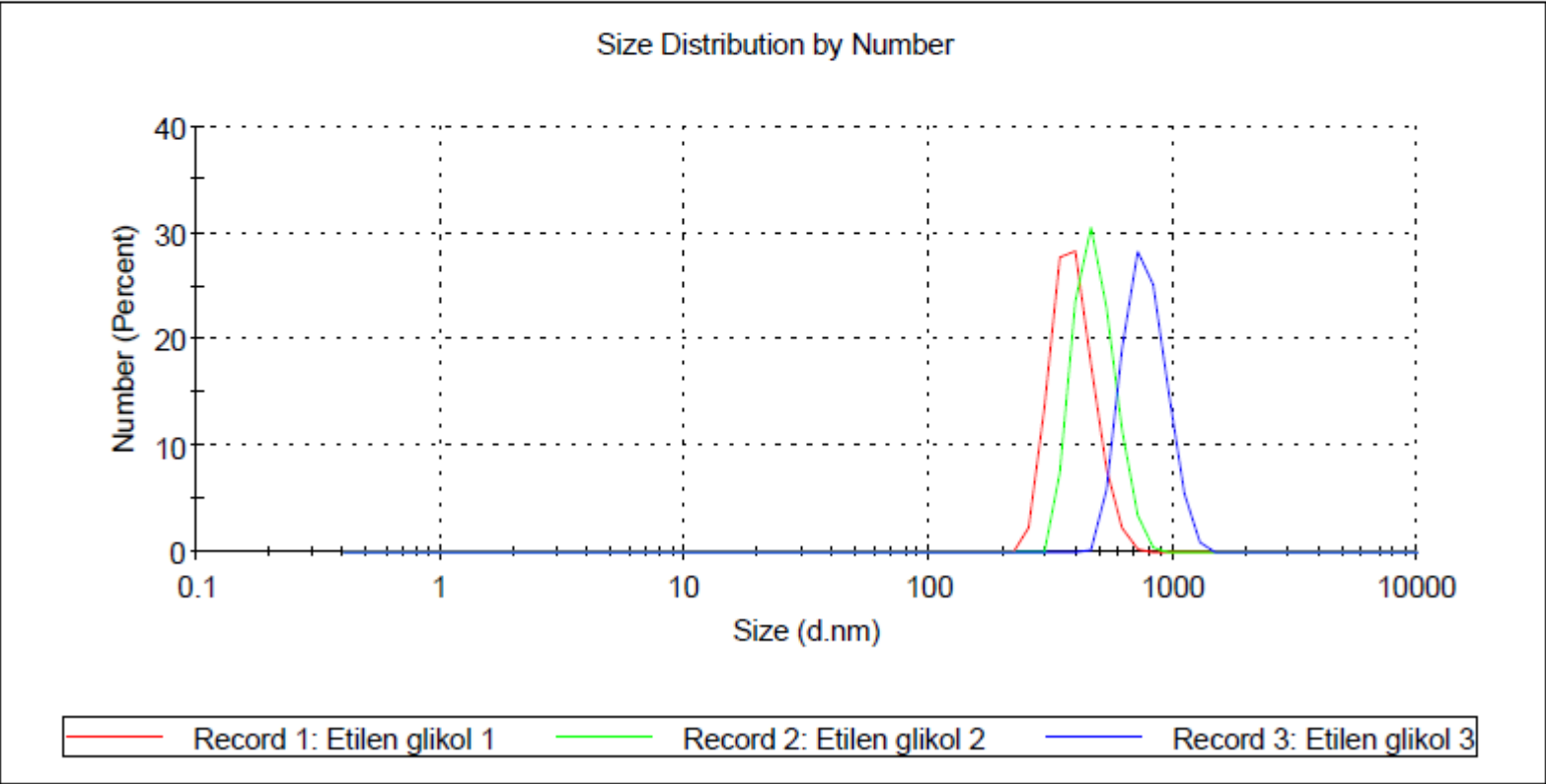
Spectrum	In stats.	C	Al	Si	Fe	Total
Spectrum 1	Yes	83.33	15.80	0.56	0.31	100.00
Mean		83.33	15.80	0.56	0.31	100.00
Std. deviation		0.00	0.00	0.00	0.00	
Max.		83.33	15.80	0.56	0.31	
Min.		83.33	15.80	0.56	0.31	

All results in weight%



Discussion and Results

		Size (d.nm):	% Number:	St Dev (d.n...	
Z-Average (d.nm):	415.2	Peak 1:	391.9	100.0	78.75
PdI:	0.323	Peak 2:	0.000	0.0	0.000
Intercept:	0.889	Peak 3:	0.000	0.0	0.000
Result quality : Refer to quality report					



Izračunate vrednosti dinamičke viskoznosti i uvećanja dinamičke viskoznosti za različite vrednosti koncentracija čestica na temperaturi 293.15 K i atmosferskom pritisku od 0.1 MPa

φ_m [wt%]	η_d [Pa·s]	η_d/η_{bf} [-]
0	0.02081	1
1	0.02238	1.075
5	0.02373	1.140
10	0.02674	1.285

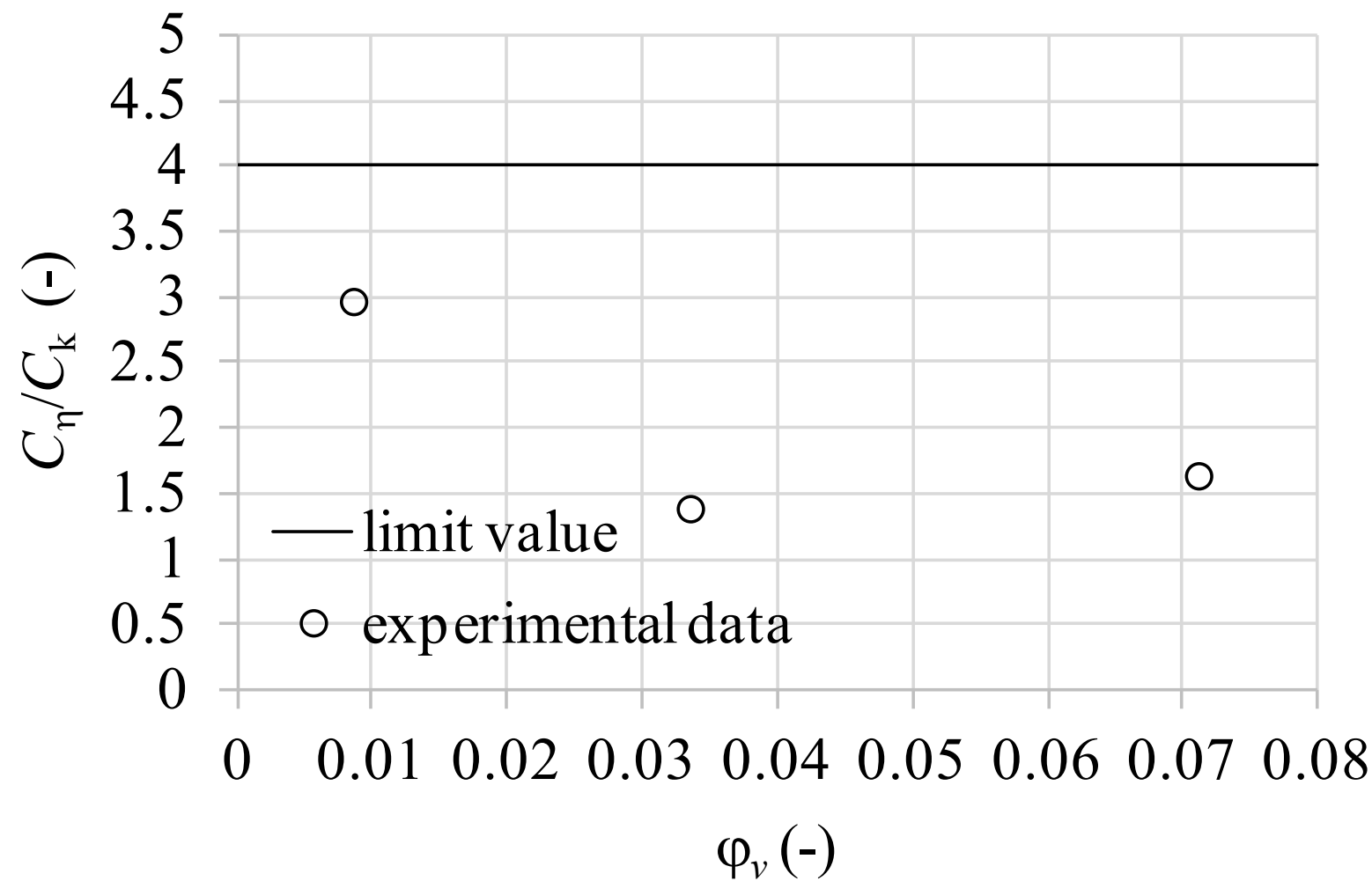
Izračunate vrednosti toplotne provodljivosti i uvećanja toplotne provodljivosti za različite vrednosti koncentracija čestica na temperaturi 293.15 K i atmosferskom pritisku od 0.1 MPa

φ_m [wt%]	k_d [Pa·s]	k_d/k_{bf} [-]
0	0.2480	1.0000
1	0.2542	1.0252
5	0.2728	1.0999
10	0.2907	1.1723

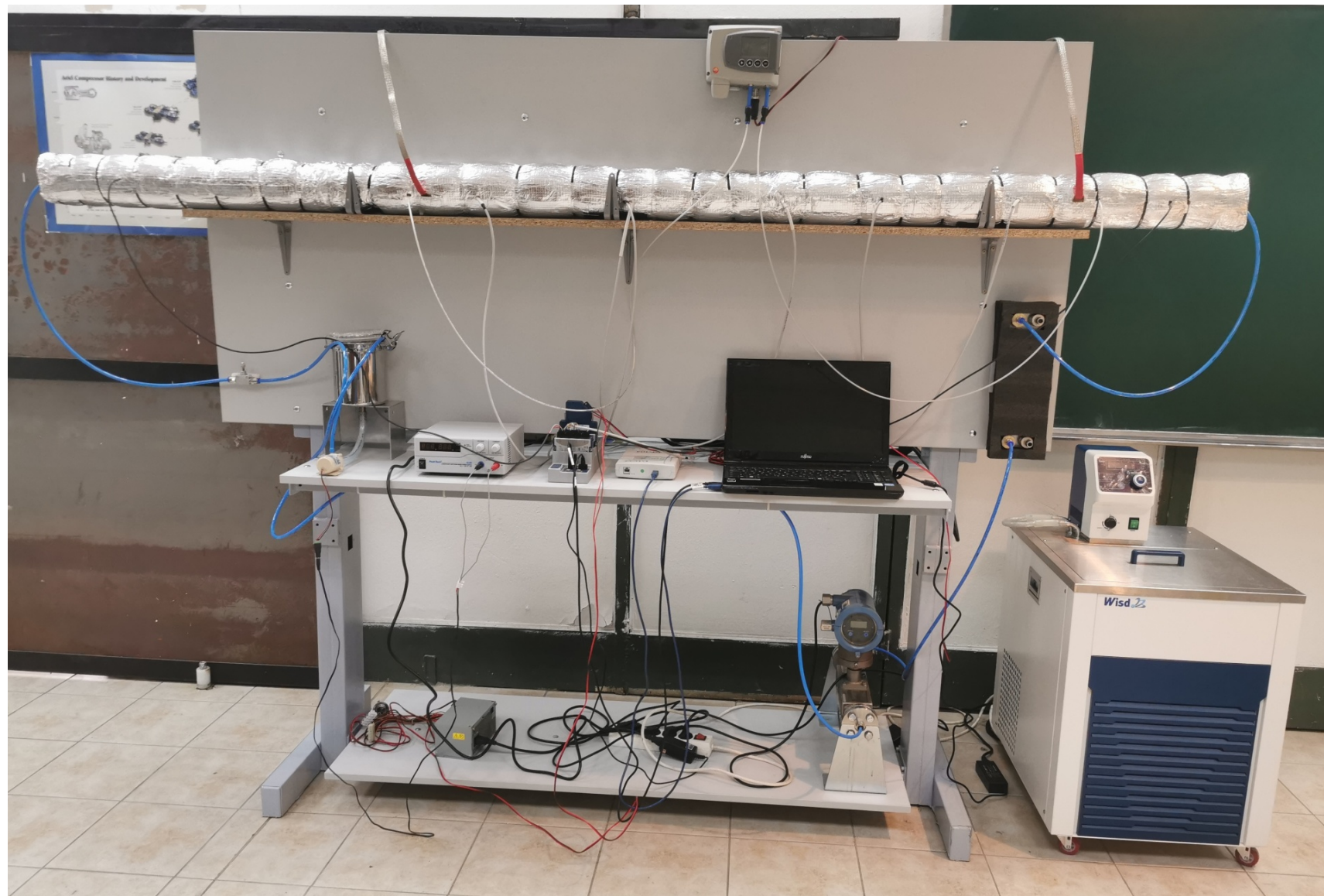
$$\frac{\eta_d}{\eta_{bf}} = 1 + 4.0996 \cdot \varphi_v$$

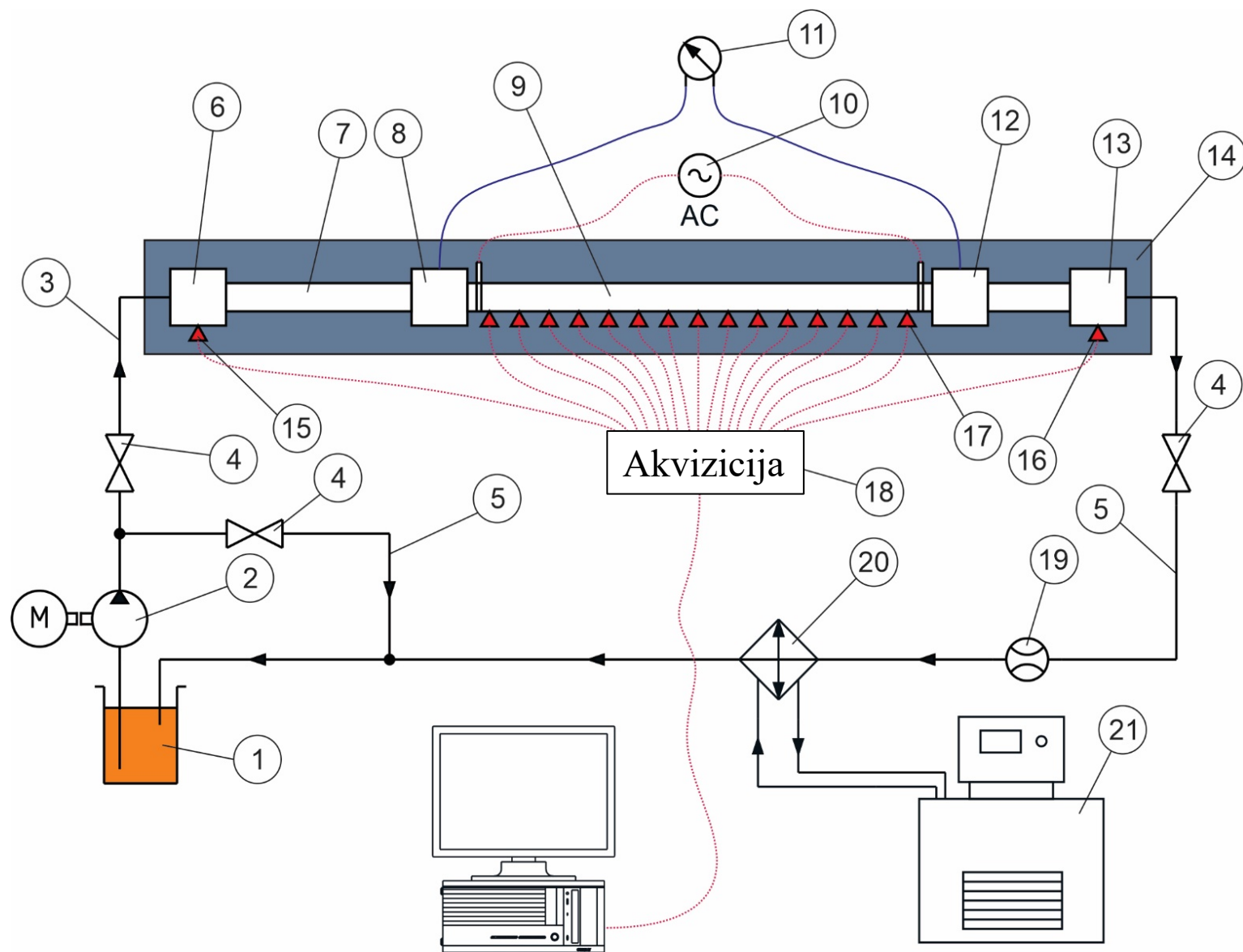
$$\frac{k_d}{k_{bf}} = 1 + 2.5384 \cdot \varphi_v$$

$$\frac{C_\mu}{C_k} < 4$$



Laboratorijsko
postrojenje za
istraživanje prinudne
konvekcije nanofluida

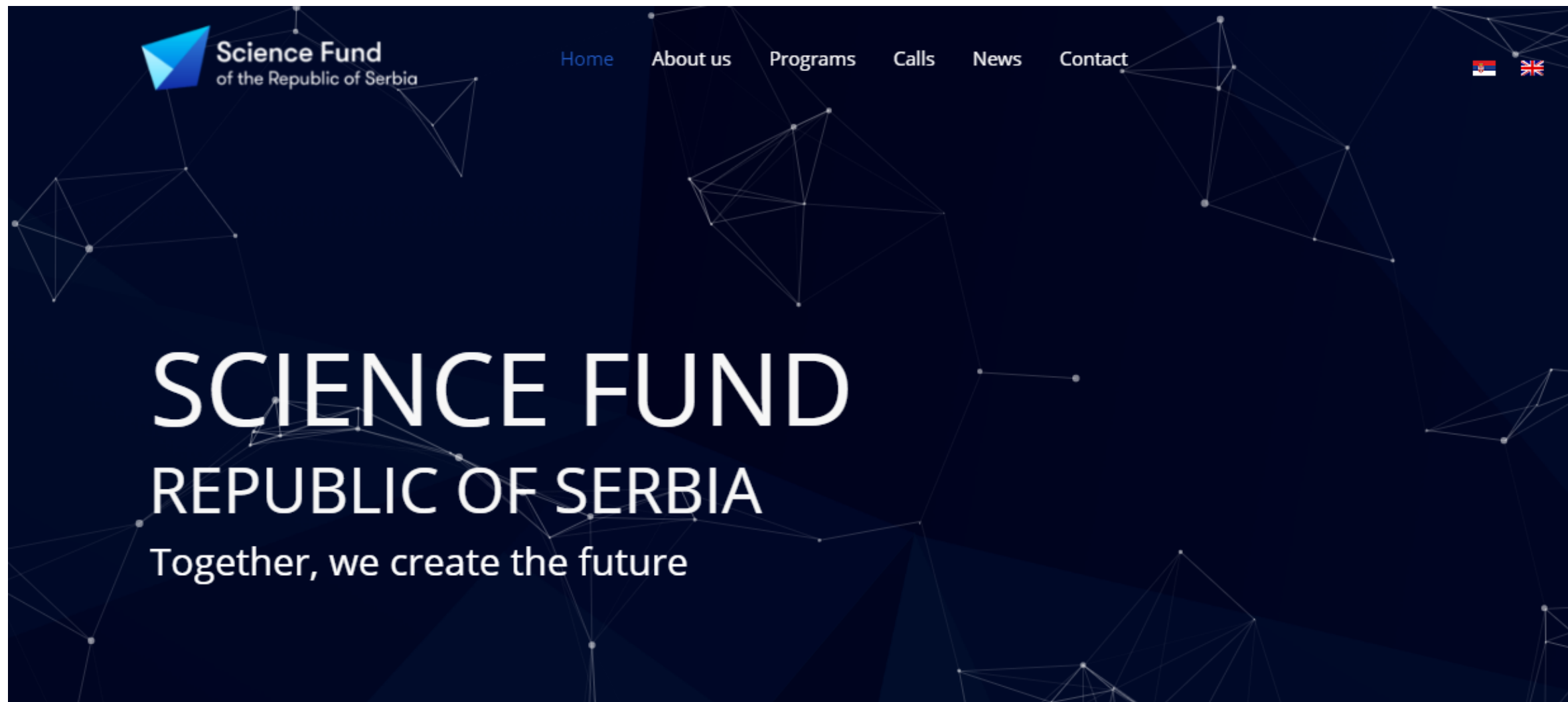




1. Rezervoar
2. Pumpa
3. Glavni vod
4. Ventili
5. Zaobilazni vod
6. Temperaturni senzor
7. Ulazna sekcija
8. Toplotna i električna izolacija
9. Ispitna sekcija
10. Ispravljač
11. Diferencijalno merilo
12. Toplotna i električna izolacija
13. Temperaturni senzor
14. Toplotna izolacija
15. PT senzor
16. PT senzor
17. PT senzori
18. Akvizicija
19. Merilo protoka
20. Izmenjivač toplote
21. Termo kupatilo

Acknowledgment

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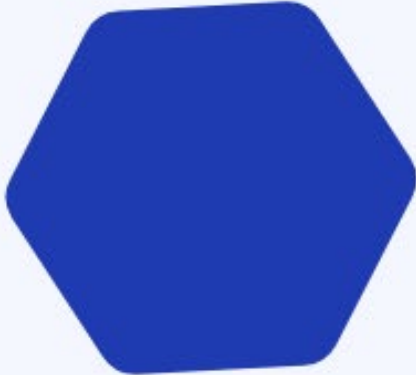


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