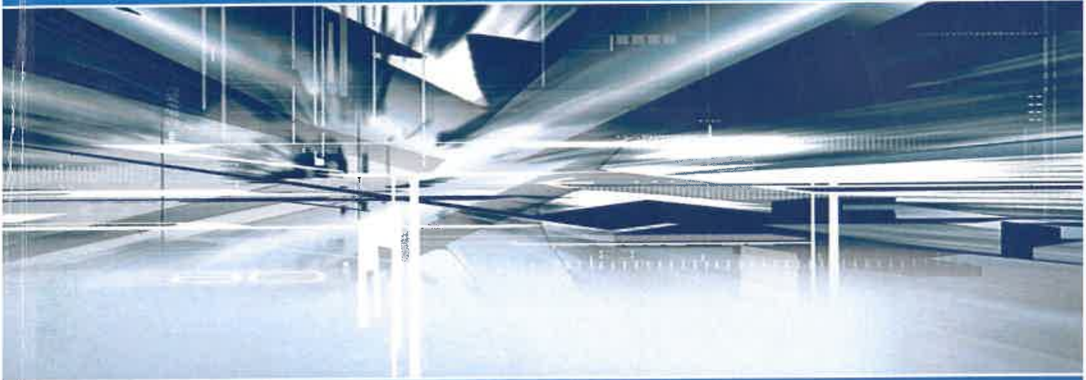
ПРОГРЕСИВНА ТЕХНІКА, ТЕХНОЛОГІЯ та ІНЖЕНЕРНА ОСВІТА



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NUMERICAL STUDY ON THE EFFECT OF AL_2O_3/WATER AND TIO_2/WATER NANOFLUIDS ON FORCED CONVECTIVE HEAT TRANSFER IN A FLAT TUBE

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Abstract

Most conventional fluids, such as water, ethylene glycol and engine oil, have limited thermal capabilities properties, which may impose restrictions in many thermal applications. On the other hand, correctly there is an extensive research that has proven that nanofluids (suspensions of nanometer-sized metallic particles in a base fluid) are better heat transfer agent than conventional fluids, *e.g.* [1]. An important application of nanofluids can be used in refrigeration systems such as automobile radiators with an important impact in the reduction of the sizes of radiators.

In this work we investigate numerically the forced convective heat transfer of two nanofluids Al_2O_3/water and TiO_2/water in a flat tube of a standard automobile radiator to quantitatively evaluate the enhanced heat transfer characteristics. The heat transfer characteristics of nanofluids under forced convection were investigated for different volumetric concentrations of nanoparticles between 0.25 and 10.0 %, and compared with the base fluid (water). The computational simulations were carried out with the *Ansys Fluent* software package.

The focus of this research is to compare the flow and heat transfer to the cases where water properties are considered constant and dependent of the temperature. To the best of our knowledge, numerical studies involving nanofluids in the flat tubes of a radiator under the conditions of the present study have not been done so far. Thus, the numerical results obtained were validated for water flow by comparing the friction factor and the Nusselt number in the flat tube with theoretical and empirical results available in the literature.

Heat transfer results are presented for temperature, convective heat transfer coefficient, heat flux, Prandtl number and Nusselt number (*Nu*) in the range of conditions studied as well as flow and nanofluids characteristics like friction factor, pressure loss, dissipated power, density, viscosity, thermal conductivity and specific heat. The results obtained with nanofluids promise efficient heat transfer to develop more efficient heat transfer fluids for use in automobile motors and industrial equipment, since the presence of alumina and titanium dioxide nanoparticles provide a greater cooling compared with the base fluid (water).

For the fluid flow in radiators, the compression work and the viscous dissipation are negligible. Under these conditions, we have numerically solved the following governing equations under a 3D flow field using the computation fluid dynamics (CFD.

$$\vec{\nabla}\cdot\vec{v}=0 \tag{1}$$

$$\rho_{nf}(\vec{v}\cdot\vec{\nabla})\vec{v}=-\vec{\nabla}p+\mu_{nf}\vec{\nabla}^2\vec{v} \tag{2}$$

$$\rho_{nf}c_{p,nf}(\vec{v}\cdot\vec{\nabla})T=k_{nf}\vec{\nabla}^2T \tag{3}$$

Many studies have shown that the low particle volumetric concentration of the nanoparticles in the base fluid makes it behave like a single-phase fluid, e.g. [1, 2]. The equations adopted in present work to the thermophysical properties of nanofluids; density, viscosity, specific heat and thermal conductivity were obtained from [3, 4]. The volumetric concentrations of nanoparticles ranged from 0.25 and 10.0 %. The properties of water and nanoparticles were withdrawn from [5, 6], Table 1.

Table1.

Properties of the nanoparticles and water at temperature of 30°C

Material	ρ (kg/m³)	c_p (J/kg.°C)	k (W/m.°C)	μ(Pa.s)
water	995.349	4179.642	0.6146	0.0007998
Al_2O_3	3880	773	36	
TiO_2	4175	692	8.4	

The geometry of the flatted tube has a larger diameter, smaller diameter and length of 9.0, 3.0 and 345 mm, respectively [7].

The system of governing Eqs. (1)–(3) was solved by the finite volume method approach using the *Fluent*. Specification on the numerical methods used can be found in our previous work [8, 9]. For all simulations performed, converged solutions were considered when the residuals resulting from the iterative process for all conservative equations were lower than 10^{-8}.

The boundary conditions used were: on the tube wall are applied the usual no-slip condition ($v = 0$) and the constant temperature condition (isothermal wall, T = 30°C); at the tube outlet was applied the condition *pressure-outlet* of *Fluent*; at the tube inlet was imposed the temperature of 90°C and in the case of the constant water properties were imposed the velocities of 0.0429 and 0.3434 m/s (calculated for Re = 250 and 2000 for water at 30 °C) and in the case of the temperature-dependent water properties were imposed the velocities 0.0172 and 0.1376 m/s (calculated for Re = 250 and 2000 for water at 90 °C).

For the choice of appropriate mesh, additional tests for water flow with constant properties at T = 30°C were carried out for Reynolds numbers from Re = 250 to 2000 in meshes with 21576, 46138, 104949 and 159962 nodes. The tests carried out using four meshes showed that the gain in accuracy of the friction factor and average Nusselt number which resulted from the use of the finest mesh (159962 nodes) was overall <2%. Then the mesh with 104949 nodes was selected for the present study.

Some of the results obtained in this research are shown in the Figures 1 and 2. Figure 1 shows the average temperature along the flatted tube. The temperature decreases along the tube and with the concentration of nanoparticles. Both nanofluids show the same behaviour. In the case of the constant water properties, Figure 1(a) and (b), for Al_2O_3 and Re = 250 the temperature decreases 46.56 K and 50.47 K for concentrations 0.0% and 10.0% respectively, whereas for Re = 2000 decreases 23.37 K and 25.58 K for concentrations 0.0% and 10.0%, respectively. For concentration of 10.0% and TiO_2/water the temperature decreases about 2 K less than for Al_2O_3/water.

In the case of the temperature-dependent water properties, Figure 1(c) and (d), the temperature decrease is more pronounced. For Al_2O_3 and Re = 250, the temperature decreases 57.03 K and 58.69 K for concentrations 0.0% and 10.0%, respectively. For Al_2O_3 and Re = 2000, the temperature decreases 33.42 K and 35.90 K for concentrations 0.0% and 10.0%, respectively. For concentration of 10.0% and TiO_2/water the temperature decreases about 1.5 K less than for Al_2O_3/water.

Figure 2 shows, for Re =250, the variations of local Nusselt number (Nu) along the line-1 and line-2 (see flat tube representation in the upper right corner of Figure 2). Line-1 is located on the plan wall and line-2 is located on the curved wall. Nu decreases along both lines however that decrease is more pronounced in the line-2 because that line is further away from the center of the tube. An increase in the nanoparticles concentration results in a decrease in Nu for both nanoparticles. However, this decrease is slightly higher for Al_2O_3.

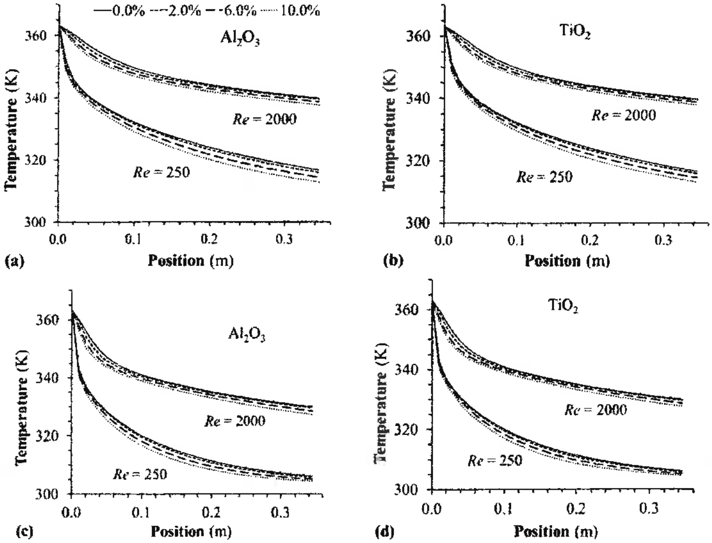

Figure 1. Temperature along the tube as a function of nanoparticle concentration, for *Re* = 250 and *Re* = 2000 at the tube inlet. For the cases of the constant water properties (a) Al_2O_3 and (b) TiO_2, and temperature-dependent water properties, (c) Al_2O_3 and (d) TiO_2.

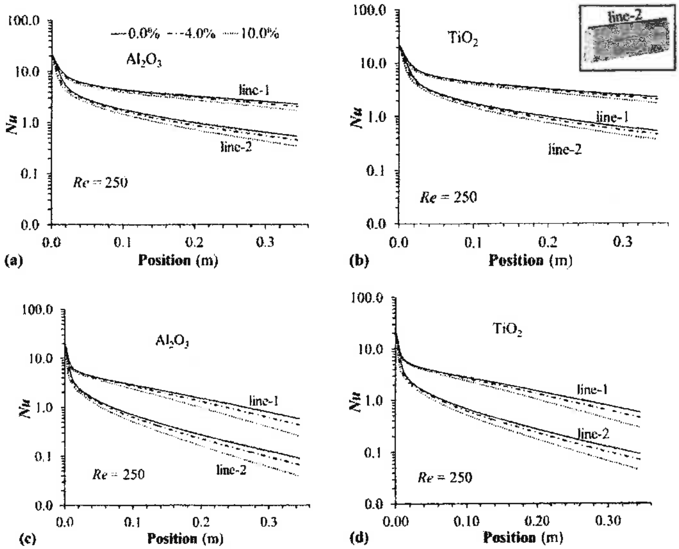

Figure 2. *Nu* along the line-1 and line-2 as a function of nanoparticle concentration, for *Re* = 250 at the tube inlet. For the case of the constant water properties (a) Al_2O_3, (b) TiO_2, and temperature-dependent water properties (c) Al_2O_3, (d) TiO_2.

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ГІДРОДИНАМІЧНА ОБРОБКА МОЛОКА ПРИ ТРАНСПОРТУВАННІ

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Анотація:

В роботі розглянуто особливості технології гідродинамічної обробки молока з використанням кавітатора під час транспортування молока. Запропоновано оригінальну схему кавітаційної обробки молока безпосередньо при транспортуванні його до пунктів призначення.

***Ключові слова**: гідродинамічна кавітація; пастеризація; молоко; кавітатор, транспортування*

У комплексі заходів щодо підвищення якості продукції, одержаної на підприємствах молочної промисловості, головну роль грають запитання, пов'язані зі зберіганням первинних властивостей молока в процесі його транспортування до місця переробки. [1]

При цьому спосіб транспортування сировини на молочний завод істотно впливає не тільки на якість одержуваної продукції, але й на економіку переробного підприємства в цілому.

Невелика кількість молока перевозиться у флягах вантажними автомобілями. При цьому способі великі витрати праці на вантажно-розвантажувальні операції і втрати молока, а умови перевезення не відповідають санітарно-гігієнічним вимогам до харчових продуктів. Якщо молока 1000 л і більше, то доцільно використовувати автоцистерни, що дозволить збільшити в два рази продуктивність праці і на 30-35% знизити транспортні витрати

Наскільки ретельно під час транспортування будуть дотримуватися всі ветеринарно-санітарні норми, залежить якість кінцевого продукту. Тому обробка молока налічує декілька етапів обробки. Одним із основних є його пастеризація. [2]

Існує велике різноманіття варіацій пастеризації молока, одним із яких є пастеризація молока гідродинамічною кавітацією.