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Numerical and Analytical Investigation of Thermal Dispersion Effects on the Heat Transfer of Nanofluid flow inside a Channel

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1- Introduction

Increasing the coefficient of heat transfer is important for all industrial applications. Ultra-high-performance can be obtained by suspending ultrafine solid particles in a convectional fluid. The thermal conductivity of solid metals is larger than fluids; therefore suspending these particles can increase thermal conductivity and heat transfer performance. This enhancement becomes more stronger as the flow speed increases and ultimately leads to an increase in the mixing effects associated with the Brownian motion of the nanoparticles. The mixing effect is called in literature as the thermal dispersion effect. This significant increase indicates that thermal dispersion is the main mechanism for convection heat transfer.

In the present study, the heat transfer of nanofluid flow inside a channel with different arrangements of nanoparticles injection (dispersive elements) is investigated. In the heat transfer phenomena, nanoparticles presence in the fluid flow is known as one of the most important factor for the thermal dispersion. In this work, the distribution of dispersive elements or nanoparticles in the channel is considered to be uniformly distributed in the central region and near the walls. The validation of results is verified by the analytical solution for a simple status of the problem and also by comparison with previous published papers. The presence of the nanoparticles in the center region, increase the Nusselt number and heat transfer characteristics with an ascending form. For the boundary arrangement, increasing the thickness of injected nanoparticles lead to an ascending-descending behavior for Nusselt number. Therefore in this distribution, the optimum thickness for dispersive elements is obtained. Also it can be seen that the presence of the nanoparticles with parabolic distribution increase the Nusselt number with a univocal form. For the exponential arrangement, especially for large values of dispersive coefficient, increasing the Nusselt number has a nonlinear behavior that is the most important distinction of these two distribution functions.

2- Mathematical Modeling

Consider the steady flow of a two-dimensional incompressible viscous nanofluid through a channel bounded by two solid horizontal walls separated by a distance of $2h$ and the length of B. According to Fig. 1, the x-axis corresponds to the central channel of the channel and the y-axis is perpendicular to it. The properties of nanofluid are assumed to be constant except for the thermal conductivity to account for thermal dispersion effects. The nanofluid flow enters the channel with uniform temperature of T_1. The uniform heat flux of q is applied to two channel walls.

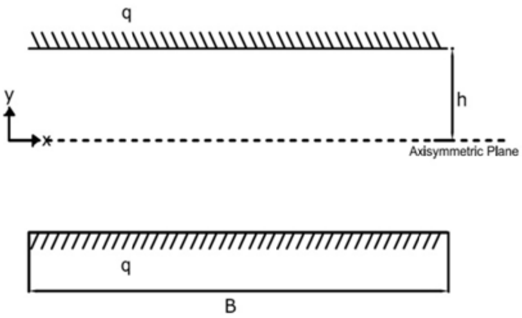

Fig. 1. Schematic diagram and the coordinate system.

The two different distributions for the injected nanoparticles into the channel are considered as shown in Fig 2. In the central distribution, the nanoparticles are injected in a region with height of $2l$ around the channel's centerline. In the boundary distribution, the nanoparticles is injected in the two region with height of l attached to the channel's plates.

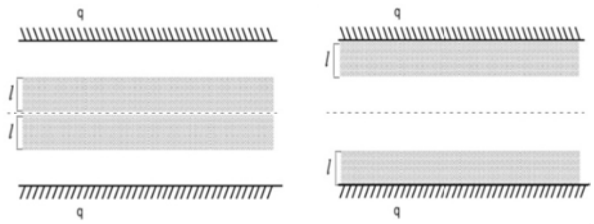

Fig. 2. The central distribution (left) and the boundary distribution (right) for injected nanoparticles.

The energy equation in this situation for the pure and nanofluid regions is presented for these distributions, separately. After the non-dimensionalizing with the suitable dimensionless variables, obtained equations are solved numerically with finite difference method. Moreover, for a special and simple case of problem includes the uniform and hydrodynamically fully developed flow, the analytical solution has been done.

3- Results

In Fig. 3, a precise comparison between the numerical and analytical results for the effect of the dispersion coefficient difference on the Nusselt number in the thermally fully developed region in the central

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distribution of the nanoparticles is presented. As can be seen, there is a very good agreement between them that indicates the correctness and accuracy of the numerical method.

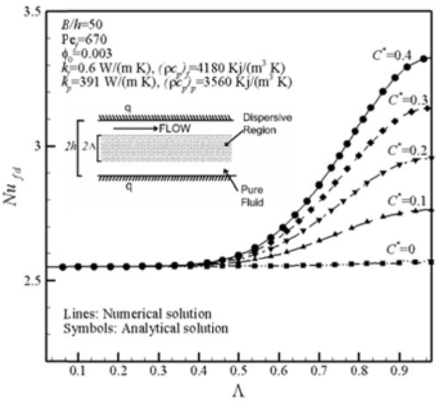

Fig. 3. Comparison between the numerical and analytical results.

In Fig. 4, the effect of the dispersion coefficient on the Nusselt number in the channel output (thermally fully developed region) is shown for the central distribution and different values of the injected nanoparticles thickness and Peclet numbers.

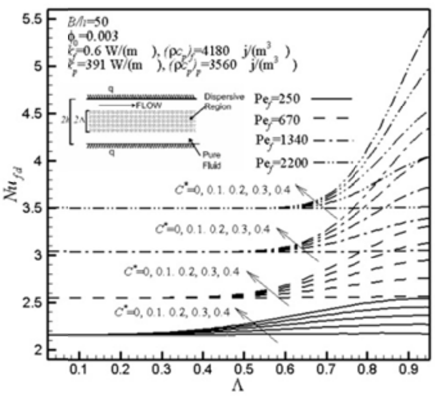

Fig. 4. Effects of the dispersion coefficient, Peclet number and the thickness of injected nanoparticles region on the Nusselt number at thermally fully developed conditions for the central distribution.

The maximum of Nusselt number on the wall occurs for the highest amount of dispersion coefficient. This trend is exacerbated with a further increase in the thickness of injected nanoparticles region. On the other hand, the direct consequence of increasing the Peclet number is rising the Nusselt number on the wall.

The effect of the dispersion coefficient on the Nusselt number in the channel output for the boundary distribution and different values of the injected nanoparticles thickness and Peclet numbers is shown in the Fig. 5. The important point is that, unlike the central arrangement, the Nusselt number in the thermally fully developed region is almost unchanged for small amounts of injected nanoparticles thickness. In the boundary arrangement, these values are different for all values of the injected nanoparticles thickness.

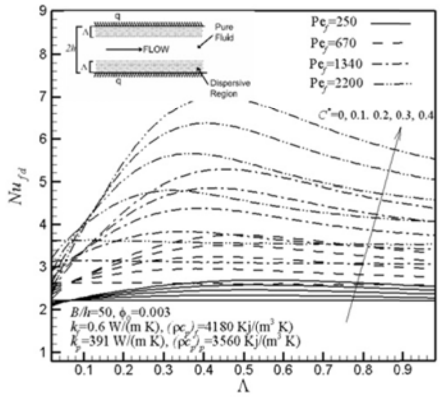

Fig. 5. Effects of the dispersion coefficient, Peclet number and the thickness of injected nanoparticles region on the Nusselt number at thermally fully developed conditions for the boundary distribution.

4- Conclusion

In this paper improvement in the heat transfer inside a channel filled with fluid with different thermal dispersion characteristics has been studied. Various distributions can be considered for nanoparticles such as central and boundary distributions. Attention to the structure and distribution of injected nanoparticle and its effects on thermal properties is most important result of this study. According to the presented results, increasing of the injected nanoparticles thickness in the central distribution increases the Nusselt number, uniformly. But in the boundary distribution, increasing of the injected nanoparticles thickness will give a downward-downward trend to the Nusselt number. Therefore in this distribution, a special thickness for the injected nanoparticles along the boundary can be considered as the optimal amount which leads to the highest Nusselt number.