Effects of wall slip and nanoparticles’ thermophoresis on the convective heat transfer enhancement of nanofluid in a microchannel

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Abstract
Heat transfer enhancement with nanofluid appears to be an attractive work in recent years. In present work, a numerical formulation based on the Buongiorno model for convective heat transfer using Al2O3-water nanofluid accounted for the effects of Brownian motions and thermophoresis of nanoparticles, slip velocity and jump temperature at solid-fluid interface. Numerical investigations for laminar forced convection flows in a rectangle channel subjected to a uniform wall heat flux have been conducted. The numerical results show us that, the slip velocity can augment the heat transfer enhancement significantly due to the increase of the convection near the solid-fluid interface. Inversely, the jump temperature is not beneficial to the convective heat transfer because of the increased thermal resistance. The thermophoresis of particles affects heat transfer enhancement by changing local density, local viscosity, and local thermal conductivity. The thermophoresis of particles influences the skin friction coefficient also. The Nusselt number increases with the Reynolds number and particle volume fraction. The impact on the Nusselt number of Reynolds number will be receded in some extent because the thermophoresis velocity will be greater when the Reynolds number increasing. These numerical results help us to design micro-devices and understand the mechanism of heat transfer enhancement by adding nanoparticles in a microchannel.

Key words : Heat transfer enhancement, Brownian motion, Thermophoresis, Slip velocity, Microchannel

1. Introduction

Heat transfer enhancement with nanofluid appears to be an attractive work in recent years because of the wide applications in the areas of microelectronic chip, micro-combustion, micro-reactor, solar energy and so on(Das, K., 2012, Saleh, R., 2014, Amin, K.B., 2011, Mahian, O., 2013) Numerous experimental and numerical studies were conducted on heat transfer enhancement of nanofluids in recent decade. Most of the research works were focused on the macroscopic thermal conductivity of nanofluids with various particle fraction, size, shape, distribution and sort etc(Timofeeva, E.V., 2011, Turkyilmazoglu, M.,2013, Hwang, K. S., 2009,Chon, C.H., 2005,Wang, X., 1999, Masoumi, N., 2009). Added nanoparticles affecting the viscosity, density, thermal conductivity of the fluid, the motion of the nanoparticles disturbing the flow, were considered to be the main factors in the initial research period (C.H., 2005, Wang, X., 1999, Masoumi, N., 2009). However, some of the experimental and numerical results were contradictory both in laminar and turbulent flows because of the unintelligible mechanism of heat transfer enhancement of nanoparticles( Wang, P., 2014, Rea, U., 2009, Tahir, S., 2012, Prabhat, 2011). These led to a controversial issue named “whether or not the anomalous convective heat transfer enhancement is possible in nanofluids” at that time. Rea, et al (2009) presented experimental evidence that no abnormal enhancement occurs, including the entrance region. Tahir, et al (2012) numerically studied laminar developing flow and heat transfer in a circular channel, and found that no
enhancement took place in the entrance region in some cases. Based on a statistical analysis methodology, Prabhat, et al (2011) found that there is anomalous heat transfer enhancement in the entrance region in nanofluid laminar flows. In fact, two main mechanisms are not considered in most of the inchoate research works. The first is the interactions between the nanoparticles and fluid. Especially, Brownian diffusion and thermophoresis of nanoparticles changed the thermal performance due to the changed particle concentration and nanofluid viscosity. The second is the velocity-slip and temperature-jump at fluid-wall interface. Buongiororno(2006) concluded that only Brownian diffusion and thermophoresis are important factors to the heat transfer enhancement in nanofluid after a theoretical analysis to estimate relative magnitudes of the terms associated with all possible slip mechanisms, namely, inertia, Brownian diffusion, thermophoresis, diffusiophoresis, Magnus effect, fluid drainage and gravity. He derived a two-component four-equation non-homogeneous equilibrium model for mass, momentum and heat transfer in nanofluids. This model were accepted by many researchers and used in their works ( Li, W., 2013, Morini G. L.,1998, Haddad, Z., 2012). Haddad et al(2012) numerically investigated the Rayleigh-Bénard convection and found that Brownian diffusion and thermophoresis greatly affected heat transfer enhancement in nanofluid, especially when the volume fraction of nanoparticles being less than 0.5%.

Some other researchers recognized that the boundary layer, especially the velocity-slip and temperature-jump at fluid-solid interface in a microchannel influenced heat transfer enhancement even more significantly( Hettiarachchi, H.D.M., 2008, Vajravelu, K., 2011, Vandadi, V., 2011, Akbarinia, A., 2011, Aminreza, N., 2012). Hettiarachchi et al(2008) numerically studied 3D laminar slip-flow and heat transfer in a rectangular microchannel with constant wall temperature and found that the local Nusselt number increased with the increased slip-velocity and the decreased jump-temperature. Vajravelu et al(2011) conducted an analysis for the convective heat transfer in a nanofluid flow over a stretching surface. The numerical results indicated that an increase in the nanoparticle volume fraction decreases the velocity boundary layer thickness while increasing the thermal boundary layer thickness. Meanwhile, the presence of nanoparticles resulted in an increase in the magnitude of the skin friction along the surface and a decrease in the magnitude of the local Nusselt number. Vandadi et al(2011) took into account the effect of velocity slip, temperature jump and viscous dissipation term, and the results showed that the viscous dissipation effect on heat transfer in microchannels is significant and should not be neglected. Akbarinia, et al (2011) investigated forced convection of Al$_2$O$_3$-water nanofluid flows in two-dimensional rectangular microchannels for heat transfer enhancement. It was found that viscous dissipation is beneficial to the heat transfer enhancement. Aminreza et al (2012) analyzed the development of the slip effects on the boundary layer flow and heat transfer over a stretching surface in the presence of nanoparticle fractions, and found that the reduced Nusselt number are strongly influenced by the slip parameter.

The numerical model used in this paper is based on the Buongiorno model for convective heat transfer in nanofluids with modifications to fully account for the effects of nanoparticles volume fraction distributions on the continuity, momentum and energy equations. Navier-Stokes and energy equations accompany with the slip velocity and the jump temperature boundary conditions expressions will be discretized using the Finite Volume Method (FVM). The Brownian motions and thermophoresis of nanoparticles will be considered to determine the heat transfer enhancement of nanofluids. Numerical investigations have been conducted for developing laminar forced convection flows in a rectangle channel subject to a uniform wall heat flux.

The Al$_2$O$_3$-water nanofluid flow and the heat transfer in rectangular microchannels have been considered. The nanofluid flow is laminar, steady state and incompressible with constant properties while dissipation, pressure work and body forces are neglected. The used properties of base fluid (water) and solid nanoparticles (Al$_2$O$_3$) (Akbarinia, A., 2011) are presented in Table 1.

| Table 1 Thermo-physical properties of nanoparticles and base fluid |
|----------------|----------------|----------------|
| properties     | Water(H$_2$O)  | Nanoparticle(Al$_2$O$_3$) |
| Density $\rho$(Kg/m$^3$) | 998.2          | 3890            |
| Heat capacitance c(J/kg K) | 4240          | 880             |
| Thermal conductivity k (W/mK) | 0.608         | 35              |
| Thermal diffusivity $\alpha$(10$^{-7}$m$^2$/s) | 1.47          | 131.7           |
| Thermal expansion coefficient $\beta$(10$^{-5}$/K) | 21            | 0.63            |
2. Mathematical formulation

2.1 Governing equations

Consider a two-dimensional viscous flow of a nanofluid in a rectangle channel subject to a uniform wall heat flux. The coordinate system and scheme of the problem is shown in Figure 1.

The flow is considered along the x-axis and the channel length is chosen 20 times the width in order to achieve hydrodynamically developed flow at the outlet.

The numerical model includes the continuity equation, Navier–Stokes equation which is still valid in current microchannel flow:

\[ \nabla \cdot \mathbf{V} = 0 \]  
\[ \rho_n \left[ \frac{\partial \mathbf{V}}{\partial t} + (\mathbf{V} \cdot \nabla)\mathbf{V} \right] = -\nabla p + \mu_n \nabla^2 \mathbf{V} + \mathbf{F} \]

where \( p \) is pressure, \( \mu_n \) is dynamic viscosity, \( \rho_n \) is density of nanofluid, \( \mathbf{F} \) is source term to account for gravity, magnetic force, electrostatic force, interfacial tension force, and so on. In this equation, the Mixture model is tightly connected, i.e., in a computational cell, the density and the viscosity of the two phase mixture should be calculated.

[Fig. 1 Schematic diagram of two-dimension rectangular microchannel]

The nanoparticle continuity and energy equations are derived from Buongiorno (2006). Brownian diffusion and thermophoresis, which are the particle motion under the influence of a thermal gradient, can be regarded as the only slip mechanisms for nanoparticle transport at low Reynolds number in microflow. They are incorporated into the nanoparticle transport equation as follows:

\[ \frac{\partial \phi_p}{\partial t} + \nabla \cdot \mathbf{V} \phi_p = \nabla \cdot \left[ D_B \nabla \phi_p + D_T \nabla T \right] \]

In the presence of nanoparticles, the energy equation takes below form:

\[ \rho_c c_n \left[ \frac{\partial T}{\partial t} + \nabla \cdot \mathbf{V} T \right] = \nabla \cdot \kappa \nabla T + \rho_p c_p \left[ D_B \nabla \phi_p \cdot \nabla T + D_T \nabla T \cdot \nabla T \right] \]

2.2 Nanofluids properties

The property field varies within the nanofluid as it is a function of particle concentration. The density, specific heat and thermal expansion coefficient of the nanofluid can be calculated using standard mixture laws:

\[ \rho_n = \left( 1 - \phi_p \right) \rho_b + \phi_p \rho_p \]
\[ c_n = \frac{(1-\phi_p)c_b\rho_b+\phi_p c_p \rho_p}{\rho_n} \]
\[ \beta_n = \frac{(1-\phi_p)\beta_p + \phi_a \beta_p \rho_p}{\rho_n} \]  

(8)

here, \( \rho_p, \rho_n, c_b, c_p, \beta_p, \beta_n \) denote density, specific heat and thermal expansion coefficient of the base fluid and nanoparticles, \( \phi_p \) denotes volume fraction of nanoparticle.

The presented expression for dynamic viscosity by Maiga et al. (2004) which was determined by available experimental results for water-Al2O3 is given as:

\[ \mu_n = (123\phi_p^2 + 7.3\phi_p + 1)\mu_b \]  

(9)

and \( \mu_b, \mu_n \) denote viscosity of the base fluid and nanofluid. It is worth mentioning that the viscosity of the base fluid (water) should be considered as a variable with temperature and the following equation is used to evaluate the viscosity of water (Tarik, A.S., 2012)

\[ \mu_b = 2.414 \times 10^{-5} \times 10^{240(T-20)} \]  

(10)

There is still a lack of accurate theoretical models for the prediction of the thermal conductivity of nanofluids.

Normally, the thermal conductivity of nanofluids based Maxwell model reads as:

\[ k_n = \frac{k_p + 2k_b + 2\phi_p(k_p - k_b)}{k_p + 2k_b - \phi_p(k_p - k_b)}k_b \]  

(11)

\( k_p, k_b \) denote thermal conductivity of the particles and thermal conductivity of the based fluid, respectively.

### 2.3 Boundary condition

The boundary conditions specify the fluid behavior and properties at the boundaries of the whole domain. The inlet velocity (x=0) in Fig. 1 is assumed to be uniform. The transverse velocity is assumed to be zero (\( v_y = 0 \)), and the inlet velocity can be calculated as:

\[ u_{in} = \frac{Re_{in}}{\rho_n H} \]  

(12)

here, \( Re \) is Reynolds number, \( H \) is characteristic dimension of the channel. The uniform heat flux of \( q \) is applied on top wall of the channel. The atmospheric pressure is assumed to be at the channel outlet with the gauge pressure value is zero. Meanwhile, the net heat transfer at bottom adiabatic wall is assumed to be zero.

The slip velocity at fluid-solid surface exists in micro and nano-scale, because in cases of micro and nano-scales the Knudsen number (\( Kn = \lambda/H, \lambda \) is mean free path) is between 0-0.1, this non-slip assumption is no longer correct for both liquid and gas flows. This fact is confirmed by Tretheway and Meinhar (2002) who measured the velocity profiles of water flowing through 30x300μm channels experimentally. They found that when a hydrophobic microchannel (uncoted glass) surface is coated with a 2.3 nm thick monolayer of hydrophobic octadecltrichlorosilane, an apparent velocity slip is measured just above the solid surface. The results of Ngoma and Erchiqui(2007) also confirm the use of slip velocity for liquid flows in micro- and nano-scale. In the present work the range of the Knudsen number is between 0-0.1, it is necessary to consider slip velocity at nano-scales (\( Kn=0.1 \)) as well as micro-scales (0<\( Kn<0.1 \)).

The non-dimensionalized velocity slip condition is expressed as (Gad-el-Hak, M., 2006):

\[ U_{slip} = I_v \frac{\partial v_x}{\partial y} + \left( \frac{2-\sigma_T}{\sigma_T} \right) Kn \frac{\partial v_x}{\partial y} \]  

(13)

Similarly, temperature-jump boundary condition resulting from Taylor series in dimensionless form can be read as:

\[ T_{jump} = I_T \frac{\partial T}{\partial y} + \left( \frac{2-\sigma_T}{\sigma_T} \right) Kn \frac{\partial T}{\partial y} \]  

(14)

Here, \( I_v, I_T \) are velocity-slip length and temperature-jump length. The values of the momentum and thermal accommodation coefficients (\( \sigma_v, \sigma_T \)) are near unity for most engineering applications.

The boundary conditions in present model are set up as follow:

1) Velocity and temperature at inlet
\[ v_{sl(x=0)} = u_{in}, v_y |_{x=0} = 0 \]
\[ T |_{x=0} = 300K \]

2) Pressure and diffusion flux at outlet
\[
p_{o|L} = 0 \\
\frac{\partial T}{\partial x}|_{x=L} = \frac{\partial v_x}{\partial x}|_{x=L} = 0
\]

3) Thermal boundary at wall
\[
q|_{y=H/2} = -k_n \frac{\partial T}{\partial y} = \text{Const.} \\
q|_{y=-H/2} = 0
\]

4) Velocity boundary at wall
\[
v_y|_{y=\pm H/2} = 0
\]

5) Wall-fluid interface
\[
v_x|_{y=\pm H/2} = \left(\frac{2 - \sigma_v}{\sigma_v}\right) Kn \frac{\partial v_x}{\partial y} \\
(T_w - T)|_{y=\pm H/2} = \left(\frac{2 - \sigma_T}{\sigma_T}\right) Kn \frac{\partial T}{\partial y}
\]

2.4 Important parameters

In heat transfer at a boundary within a fluid, the Nusselt number (Nu) is the ratio of convective to conductive heat transfer across (normal to) the boundary, it can be defined as:

\[
Nu = \frac{hH}{k_n} \quad (15)
\]

where, \( h \) is the convective heat transfer coefficient of the fluid written as:

\[
h = \frac{q}{\Delta T} = \frac{q}{T_w - T_{av}} \quad (16)
\]

where, \( q \) is the heat flux at the wall, \( T_w \) is the wall temperature, \( T_{av} \) is the local mean temperature of the fluid in the plane perpendicular to the wall. In the case of constant heat flux, \( q \) is known to us, \( T_w \) and \( T_{av} \) is obtained from the solution data. In the case of constant temperature boundary condition, \( T_w \) is known, and \( T_{av} \) are obtained from the solution. Average Nusselt number is obtained by integrating the expression over the range of interest.

The important physical quantities of interest in this problem are the skin friction coefficient \( C_f \), Reynolds number \( Re \), Prandtl number \( Pr \), they can be respectively defined as:

\[
C_f = \frac{\tau_w}{\rho u_n}, \quad Re = \frac{\rho u_n H}{\mu}, \quad Pr = \frac{\mu c_n}{k_n}
\]

The non-dimensionalized velocity, length, temperature, nanoparticle volume fraction read as:

\[
U = \frac{v}{u_n}, \quad X = \frac{x}{H}, \quad Y = \frac{y}{H}, \quad \theta = \frac{T_w - T}{T_w - T_0}, \quad \phi = \frac{\phi}{\phi_0}
\]

3. Numerical modeling

In spite of symmetric geometry, the whole domain should be discretized because of asymmetric boundary condition. A large number of grid points are used at fluid-wall interface to resolve the developing flow region and large velocity and thermal gradients. The finite volume method is employed to model the fluid domain. The governing equations are solved iteratively. The standard SIMPLExC algorithm is used to solve the pressure equation whereas the second order upwind scheme is used for both the momentum and energy conservation equations. The nanofluid is modeled using Eulerian–Eulerian at which both fluid and solid are assumed to be continuum. In order to implement the slip boundary condition, the control volume adjacent to the wall should be fully analyzed. It is known, the slip velocity and jump temperature at the wall are given by Eqn. (13) and (14). By using a first order approximation for the normal velocity gradient in Eqn.(13) and normal temperature gradient in Eqn(14), the slip velocity and jump temperature can be expressed as a function of the neighboring velocity and temperature(Hettiaraechchi, H.D.M., 2008).

4. Results and discussion

4.1. Model validation

The validation of grid dependency was conducted to ensure the accuracy of the numerical results, and found that a
grid system 5001×501 is fine enough for considered microchannel with the dimension of 1000×100 μm. Then, we calculated the velocity profile and compared with the published results. Figure 2 is the velocity profiles with slip boundary condition and no-slip boundary condition, it is found that the numerical results are good agreement with that in Reference of Renksizbulut (2006). This can verify the validation of present model and procedure.

4.2 Temperature profiles and nanoparticles distribution

For nanofluids with different bulk mean particle volume fractions (ϕ = 0.02, 0.2, 2.0) and pure fluid (ϕ=0), the temperature profiles were calculated under various Reynolds number from 0.025-250. The inlet velocities were calculated via equation 12. Figure 3 is the contours of temperature under Reynolds number being 0.025, 0.25, 2.5 and 25. Figure 4 shows us the non-dimensionalized temperature profiles at two positions (x=5H and x=10H) with and without temperature-jump boundary conditions (The values of the momentum and thermal accommodation coefficients are set to be unity in this case). It is found that, the temperature gradient near the wall with uniform heat flux is smaller when jump-temperature condition enforced. It results in variations of particle thermophoresis velocity and particle volume fraction distribution. It may be an important factor influencing heat transfer enhancement in nanofluid. Moreover, the temperature gradient near the upper wall is smaller at the position of x=10H than that at x=10H, therefore, we can predict that the thermophoresis velocity should be smaller at position x=10H than that x=5H.
Figure 5 is the contours of non-dimensionalized nanoparticle volume fraction. The contours are obviously asymmetric. The reason should be that, the temperature gradient in the vicinity of the wall with uniform heat flux being great will cause big thermophoresis force and violent thermophoresis, and the nanoparticles will migrate away from the top wall. On the contrary, only a lift force caused by the wall drives the nanoparticles away from the bottom wall. Figure 6 shows us non-dimensionalized nanoparticle volume fraction profile at various section x=0, 2H, 3H, 4H, 5H. Firstly, the volume fraction profile is distorted except that at inlet because the nanoparticles migrate from the hot wall. Secondly, the volume fraction near the hot wall decreases gradually in the stream direction, while the volume fraction accordingly increases in the region away from the hot wall. Not expected is that, the volume fraction in the vicinity of cold wall is under the mean value, this can be attributed to the wall effect caused by shear lift. Combining thermophoresis and wall effect, the nanoparticle volume fraction profiles present two waves, the smaller wave being close to the cold wall. The final result shown that two waves are superposed to be a more bigger wave at Y≈0.3 when x≥5H).

4.3 Effect of slip-velocity and jump-temperature on Nusselt number

It is known to us that, nanoparticles’ motion due to the Brownian motion and thermophoresis, aggregation morphology and deposits structure on the wall affect the slip at solid-liquid interface in microchannel obviously but complicately. And the velocity slip and temperature jump can significantly affect the local Nusselt number in the case of slip-flow. According to the Buongiorno model, Brownian motion and thermophoresis are two of the most important factors on the heat transfer enhancement. In order to clarify the influence of velocity slip and temperature jump on heat transfer enhancement, we concentrated in this work not on the slip mechanism but on the effects of slip length. Figure 7 shows us the local Nusselt number for different thermal and momentum accommodation coefficients. We can see from this figure that, the Nusselt number is greater when slip-velocity being bigger and jump-temperature being smaller. The reason should be that, the velocity slip increases the advection near the walls causing an increase in the heat transfer, whereas the temperature-jump increases the thermal resistance at wall–fluid interface resulting in a decrease in the heat transfer. However, the combined effect of velocity slip and temperature jump could increase or decrease the heat transfer depending on their relative magnitude. We can see in Fig.7 when the thermal and momentum accommodation coefficients both are set to be unit, the local Nusselt number is almost equal to that of no-slip flow (i.e. both σ_T and σ_V = 2). Our numerical results agrees very good with that of Yu (2001). In addition, the decrement or increment of Nusselt number at entrance region is much more significant than that at x≥ 5H, what is due to the presence of large temperature jump at the beginning of the entrance region that results in a great drop in Nusselt number. As the flow develops, velocity slip effect becomes more dominant over the temperature jump effect resulting in an increase of Nusselt number.
4.4 Effect of particle volume fraction on Nusselt number

Effect of nanoparticle concentration on heat transfer enhancement has been studied by many researchers in recent years. With regret, the mechanism is not clear by now. We calculated local Nusselt number for three cases with the nanoparticles volume fraction $\phi = 0$, 0.2% and 2.0%. A great rise of Nusselt number can be seen in Figure 8 when nanoparticle added in based fluid even only 0.2% volume fraction. This is because the nanoparticle can increase the thermal conductivity of nanofluid, resulting in a thick thermal boundary layer, a thin momentum boundary layer, a low temperature gradient, a high velocity gradient, and ensued great Nusselt number. Unlike expectation, Nusselt number of volume fraction $\phi = 2.0\%$ is not notable greater than that of $\phi = 0.2\%$. The reason may be that, decrement of temperature gradient of added more nanoparticle is not so remarkable as that of decreased thermal conductivity.

4.5 Effect of thermophoresis on Nusselt number and skin friction coefficient

As is known to all, the thermophoresis is related to temperature gradient and nanoparticles concentration. It is acceptable to us that thermophoresis will influence Nusselt number certainly. We conducted numerical simulations for
various thermophoresis parameters $\beta=1 \times 10^{-3}, 5 \times 10^{-3}$ at Reynolds number ranging from 0.025-250. Figure 9 shows us that: 1) the Nusselt number increases with the increase of Reynolds number because of great convection at high Reynolds number. 2) Great thermophoresis parameter results in the drop of Nusselt number. The reason is the same as that described in 4.2. 3) The greater the Reynolds number is, the greater the Nusselt number falls. The likely reason is high Reynolds number resulting in great thermophoresis velocity.

We calculated the average skin friction coefficients near top wall specific to various velocity slip ranging from 0-19 (i.e. $\sigma_v=2-0.1$) and nanoparticle volume fraction($\phi=0, 2.0\%$). It is found from Figure 10 that, the smaller the momentum accommodation coefficients are, the less the average skin friction coefficients are. The likely reason should be that, the nanoparticle reduces the thickness of momentum boundary layer, increases the shear rate, and induces higher skin friction coefficient.

![Fig. 10 Effect of velocity-slip on skin friction coefficient with and without nanoparticles](image)

5. Conclusions

The numerical model based on the Buongiorno model for convective heat transfer using Al$_2$O$_3$-water nanofluid accounts for the effects of nanoparticles distributions, Brownian motions and thermophoresis of nanoparticles on the continuity, momentum and energy equations. Navier-Stokes and energy equations accompanying with the slip velocity and the jump temperature have been discretized by the Finite Volume Method (FVM). Numerical investigations for developing laminar forced convection flows in a rectangle channel subjected to a uniform wall heat flux have been conducted, and following conclusions can be drawn:

1) The numerical formulation based on Buongiorno model can involve the effects of Brownian motions and thermophoresis of nanoparticles, and can enforce velocity slip and temperature jump boundary conditions. The validity of this model was verified by comparing the numerical results with published results.

2) The velocity slip and temperature jump boundary conditions can influence the velocity and temperature distribution obviously. The velocity slip can intensify the convective heat transfer significantly due to the enhancement of the convective near the solid-fluid interface. Inversely, the jump temperature is not beneficial to the convective heat transfer because of the thermal resistance increment.

3) The thermophoresis of particles influences the particle contribution, changes the local density, viscosity, thermal conductivity, and affects sequentially convective heat transfer efficiency. The Nusselt number increases with the Reynolds number and particle volume fraction. The impact on the Nusselt number of Reynolds number will be receded to some extent, because the thermophoresis velocity becomes greater when the Reynolds number increases.

4) The smaller the momentum accommodation coefficient is, the less the average skin friction coefficient is.

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