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MIXED CONVECTION BOUNDARY LAYER ON A SOLID SPHERE WITH CONSTANT SURFACE HEAT FLUX

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ABSTRACT

The steady mixed convection boundary layer flow of an incompressible viscous fluid on a solid sphere with a constant surface heat flux q_w is considered for both the assisting and the opposing flow cases. The transformed governing equations of the non-similar boundary layers are solved numerically using the Keller-box method. Numerical results are presented for different values of the mixed convection parameter λ and for the Prandtl number, Pr = 0.7 (air) and Pr = 7 (water). The numerical results obtained include local skin friction coefficient C_f, local wall temperature distribution $\theta_w(x)$, velocity and temperature profiles. It is found that the assisting flow ($\lambda > 0$) delays the separation of the boundary layers, and if the assisting flow is strong enough, it suppresses the separation completely. On the other hand, the opposing flow ($\lambda < 0$) brings the separation point nearer to the lower stagnation point ($x \approx 0$) of the sphere, and for sufficiently strong opposing flows, there will not be a boundary layer on the sphere.

Keywords: mixed convection; boundary layer; solid sphere; constant heat flux

ABSTRAK

Aliran lapisan sempadan olakan campuran mantap bagi bendalir likat tak termampatkan pada sfera pejal dengan fluks haba permukaan malar q_w dipertimbangkan bagi kedua-dua kes aliran membantu dan menentang. Persamaan-persamaan menakluk terjelmakan bagi lapisan sempadan tak serupa diselesaikan secara berangka menggunakan kaedah kotak Keller. Keputusan berangka diberikan terhadap beberapa nilai parameter olakan campuran λ yang berbeza dan juga nombor Prandtl Pr = 0.7 (udara) dan Pr = 7 (air). Keputusan berangka yang diperoleh meliputi pekali geseran kulit setempat C_f, taburan suhu dinding setempat $\theta_w(x)$, serta profil-profil halaju dan suhu. Didapati bahawa aliran membantu ($\lambda > 0$) melambatkan pemisahan lapisan sempadan, dan jika aliran membantu tersebut begitu kuat, ia akan sepenuhnya menghalang pemisahan daripada terjadi. Sebaliknya, aliran menentang ($\lambda < 0$) menyebabkan titik pemisahan semakin hampir kepada titik genangan bawah ($x \approx 0$) sfera tersebut, dan bagi aliran menentang yang cukup kuat, maka tidak akan wujud lagi lapisan sempadan pada sfera tersebut.

Kata kunci: olakan campuran; lapisan sempadan; sfera pejal; fluks haba malar

References

Antar M.A. & El-Sharawi M. 2002. Mixed convection around a liquid sphere in an air stream. *Heat & Mass Transfer* **38**: 419–424.

Cebeci T. & Bradshaw P. 1988. *Physical and Computational Aspects of Convective Heat Transfer*. New York: Springer-Verlag.

Chen T.S. & Mucoglu M. 1978. Mixed convection about a sphere with uniform heat flux. *J. Heat Transfer* **100**: 542–544.

El-Sharawi M., Ahmad N.T. & Kodah Z. 1990. Mixed convection about a rotating sphere in an axial stream. *Numerical Heat Transfer, Part A* **18**: 71–93.

Farouk B. 1985. Mixed convective flows around a slowly rotating isothermal sphere. *J. Heat Transfer* **107**: 431–438.

Hieber C.A. & Gebhart B. 1969. Mixed convection from a sphere at small Reynolds and Grashof numbers. *J. Fluid Mech.* **38**: 137–159.

Klaychko L.S. 1963. Heat transfer between a gas and a spherical surface with the combined action of free and forced convection. *J. Heat Transfer* **85**: 355–357.

Le Palec G. & Daguenet M. 1987. Laminar three-dimensional mixed convection about a rotating sphere in stream. *Int. J. Heat & Mass Transfer* **30**: 1511–1523.

Lien F.-S. & Chen C.-C. 1987. Mixed convection of micropolar fluid about a sphere with blowing and suction. *Int. J. Engng. Sci.* **24**: 775–784.

Nazar R., Amin N. & Pop I. 2002. On the mixed convection boundary-layer flow about a solid sphere with constant surface temperature. *Arabian J. Sci. Engng.* **27**: 117–135.

Nazar R., Amin N. & Pop I. 2003. Mixed convection boundary layer flow about an isothermal sphere in a micropolar fluid. *Int. J. Thermal Sciences* **42**: 283–293.

Pop I. & Ingham D.B. 2001. *Convective Heat Transfer: Mathematical and Computational Modelling of Viscous Fluids and Porous Media*. Oxford: Pergamon.

Yuge T. 1960. Experiments on heat transfer from spheres including combined natural and forced convection. *J. Heat Transfer* **82**: 214–220.

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