

NUMERICAL SOLUTIONS OF FREE CONVECTION BOUNDARY LAYER FLOW ON A HORIZONTAL PLATE

(Penyelesaian Berangka bagi Aliran Lapisan Sempadan Olakan Bebas pada Plat Mengufuk)

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ABSTRACT

In this paper numerical solutions are obtained for the steady laminar free convection boundary layer flow on a horizontal plate with variable wall temperature. The governing non-dimensional boundary layer equations are transformed into ordinary differential equations using similarity transformation, which are then solved numerically using an implicit finite difference scheme known as the Keller-box method. The numerical results for different values of the Prandtl number Pr and the constant m representing the power index are obtained. The effects of various values of Prandtl number Pr and m on the velocity profiles, temperature profiles, skin friction and heat transfer coefficients are presented and discussed.

Keywords: boundary layer; free convection; horizontal plate; similarity solutions

ABSTRAK

Dalam makalah ini penyelesaian berangka diperoleh bagi masalah aliran lapisan sempadan olakan bebas mantap dan berlamina terhadap plat mengufuk dengan suhu dinding boleh ubah. Persamaan menakluk lapisan sempadan tak berdimensi dijelma kepada bentuk persamaan pembezaan biasa menggunakan penjelmaan keserupaan. Persamaan yang diperoleh diselesaikan secara berangka menggunakan skim beza terhingga tersirat, iaitu kaedah kotak Keller. Keputusan berangka bagi beberapa nombor Prandtl Pr dan pemalar m diperoleh. Kesan nilai Pr dan m yang berbeza ke atas profil halaju, profil suhu, pekali geseran kulit dan pekali pemindahan haba diutara dan dibincangkan.

Kata kunci: lapisan sempadan; olakan bebas; plat mengufuk; penyelesaian keserupaan

References

- Ackroyd J.A.D. 1976. Laminar natural convection boundary layers on near-horizontal plates. *Proc. Roy. Soc. London A* **352**: 249-274.
- Afzal N. 1985. Higher order effects in natural convection flow over a uniform flux horizontal surface. *Wärme- und Stoffübertr* **19**: 177-180.
- Afzal N. & Hussain T. 1986. Effects of large suction in natural convection boundary layer on a horizontal plate. *Wärme- und Stoffübertr*. **20**: 203-206.
- Brouwers H.J.H. 1993. The effect of blowing or suction on laminar free convection heat transfer on flat horizontal plates. *Wärme- und Stoffübertr* **28**: 341-344.
- Clifton J.V. & Chapman A.J. 1969. Natural convection on a finite-size horizontal plate. *Int. J. Heat Mass Transfer* **12**: 1573-1584.
- Chen T.S., Buchanan W.P. & Armaly B.F. 1993. Natural convection on vertical and horizontal plates with vectored surface mass transfer. *Int. J. Heat Mass Transfer* **36**: 479-487.
- Chen T.S., Tien H.C. & Armaly B.F. 1986. Natural convection on horizontal, inclined, and vertical plates with variable surface temperature or heat flux. *Int. J. Heat Mass Transfer* **29**: 1465-1478.
- Cebeci T. & Bradshaw P. 1984. *Physical and Computational Aspects of Convective Heat Transfer*. New York: Springer-Verlag.

- Daniels P.G. 1992. A singularity in thermal boundary-layer flow on a horizontal surface. *J. Fluid Mech.* **242**: 419-440.
- Goldstein R.J., Sparrow E.M. & Jones D.C. 1973. Natural convection mass transfer adjacent to horizontal plates. *Int. J. Heat Mass Transfer* **16**: 1025-1035.
- Gill W.N., Zeh D.W. & Del Casal D. 1965. Free convection on a horizontal plate. *Z. J. Appl. Math. Phys. (ZAMP)* **16**: 539-541.
- Jones D.R. 1973. Free convection from a semi-infinite plate inclined at a small angle. *Quart. J. Mech. Appl. Math.* **26**: 77-98.
- Kitamura K. & Kimura F. 1995. Heat transfer and fluid flow of natural convection adjacent to upward-facing horizontal plates. *Int. J. Heat Mass Transfer* **38**: 3149-3159.
- Lin H.-T. & Yu W.-S. 1988. Free convection on a horizontal plate with blowing and suction. *J. Heat Transfer* **110**: 793-796.
- Lin H.-T., Yu W.-S. & Yang S.-L. 1989. Free convection on an arbitrarily inclined plate with uniform surface heat flux. *Wärme- und Stoffübertr.* **24**: 183-190.
- Mahajan R.L. & Gebhart B. 1980. Higher-order boundary layer effects in plane horizontal natural convection flows. *J. Heat Transfer* **102**: 368-371.
- Noshadi V. & Schneider W. 1999. Natural convection flow far from a horizontal plate. *J. Fluid Mech.* **387**: 227-254.
- Pera L. & Gebhart B. 1973. Natural convection boundary layer flow over horizontal and slightly inclined surfaces. *Int. J. Heat Mass Transfer* **16**: 1131-1146.
- Rotem Z. & Claassen L. 1969. Natural convection above unconfined horizontal surfaces. *J. Fluid Mech.* **38**: 173-192.
- Raju M.S. Liu X.Q. & Law C.K. 1984. A formulation of combined forced and free convection past horizontal and vertical surfaces. *Int. J. Heat Mass Transfer* **27**: 2215-2224.
- Stewartson K. 1958. On the free convection from a horizontal plate. *J. Appl. Math. Phys. (ZAMP)* **9**: 276-282.
- Yu W.-S. & Lin H.-T. 1988. Free convection heat transfer from an isothermal plate with arbitrary inclination. *Wärme- und Stoffübertr.* **23**: 203-211.

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