The interaction of the wake with the potential flow in mixed convection flow past a horizontal plate

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The effect of weak buoyancy on the laminar flow of a fluid with kinematic viscosity ν, isobaric expansion coefficient β past a isothermally heated horizontal plate of length L and temperature $T_\infty + \Delta T$ is aligned under a small angle of attack ϕ to the oncoming free stream (velocity U_∞, temperature T_∞) will be investigated in the distinguished limit of large Reynolds numbers Re with the "reduced" buoyancy parameter $\kappa = \mathrm{GrRe}^{-9/4} = \mathrm{O}(1)$ and the inclination parameter $\lambda = \phi\kappa\mathrm{Re}^{1/4}$ being of order one and where the Grashof number $\mathrm{Gr} = \mathrm{g}\beta\delta\mathrm{TL}^3/\nu^2$ is defined in the usual way.

Considering a large Reynolds number Re temperature and density perturbations are limited to a thin boundary layer and wake, respectively. An essential assumption to determine the perturbation of the outer flow field is the validity of the Kutta condition. Thus a vortex distribution on the wake and the plate can been introduced to compensate the hydrostatic pressure differences at the trailing edge and across the wake. Due to the inclination of the wake, which is determined by the outer potential flow, the flow in the wake is accelerated or decelerated by the tangential (to the wake) component of the hydrostatic pressure gradient. Thus the wake and the potential flow interact and have to be determined simultaneously.

By considering the limiting behavior of the wake for large distances from the plate it can be observed that solutions exists (in case of a heated plate) only for positive angles of attack, such that the fluid in the wake is accelerated. Keeping the inclination parameter λ constant and increasing the buoyancy parameter κ we observe that the wake a few plate lengths after the trailing edge bends downward (see figure 1) and the flow in the wake decelerates there[1]). A numerical investigation delivers solutions only up to a critical number of the buoyancy parameter κ depending on the angle of attack. Solutions will be presented and discussed. Finally it can be shown that the lift coefficient is markedly reduced by buoyancy.

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[1]Lj. Savić and H. Steinrück, TAM 32, 1-19,2005.

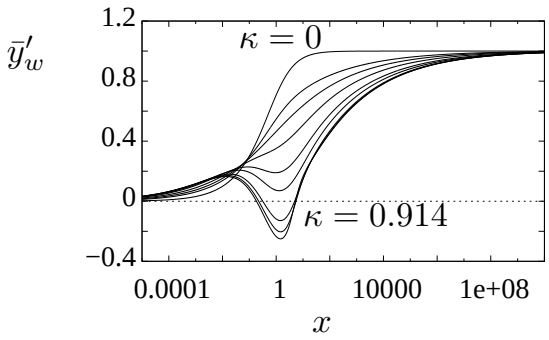

Figure 1: Scaled inclination of wake for different buoyancy parameters κ and $\lambda = 1$.