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Buoyancy effect on the wake of a confined circular cylinder during opposing laminar mixed convection heat transfer

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Abstract. Particle image velocimetry (PIV) measurements are carried out in an experimental investigation of transient laminar opposing mixed convection to assess the thermal effects on the wake of an isothermal circular cylinder placed horizontally and confined inside a vertical closed-loop downward rectangular water channel. The buoyancy effect on the flow distributions are revealed for flow conditions with Reynolds number based on cylinder diameter of Re=170, blockage ratio D/H=0.287, aspect ratio, L/D=6.97 and values of the buoyancy parameter (Richardson number) of Ri=0 and 1. Results show that the wake closure length and Strouhal number slightly decrease for increasing Richardson number.

Introduction

Vortex shedding associated with the flow past a bluff body represents a classical problem in fluid mechanics because of its rich flow physics. In particular, a vast amount of literature exists for the flow past a circular cylinder over a wide range of Reynolds numbers, as is evident in the following extensive reviews [1-4]. In contrast, although the problem of mixed convection heat transfer from a circular cylinder has received considerable attention in recent years because of its numerous engineering applications, reference results in mixed convection heat transfer past a circular cylinder are relatively sparse. Ribeiro et al. [5] performed an experimental and numerical investigation on the laminar steady flow around a confined cylinder placed in a rectangular duct with a 50% blockage ratio duct and presented results for flow patterns, streamwise velocity profiles along the cylinder centerline, contours of normalized pressure and recirculation bubble length for aspect ratios of AR=2, 6 and 16. Kannaris et al. [6] presented two- and three-dimensional direct numerical simulations of the flow around a circular cylinder placed symmetrically in a plane channel for a Reynolds number range of 10 to 390 and blockage ratio of 0.2 to investigate the confinement effect due to the channel's stationary walls on the force coefficients, the associated Strouhal numbers and generated flow regimes. Their results suggest that up to Re=180, the flow remains two-dimensional, while for higher values, Re≥210, the flow develops three-dimensional effects. Hu and Koochesfahani [7] conducted experiments using molecular tagging velocimetry and thermometry (MTV&T) to reveal the thermal effects on the wake flow pattern and wake vortex shedding process behind a circular cylinder operating in the contra-flow mixed convection regime at Re=135 and for a Richardson number range of 0.0 to 1.04 and presented results for the ensemble-averaged velocity and temperature distributions, velocity variation along the wake centerline, wake closure length, drag coefficient of the heated cylinder and average Nusselt number. Their results demonstrate that significant modifications in the flow characteristics occur due to thermally induced effects.

While much information is available on aspect ratio and end effects on vortex dynamics in the cylinder wake, there are relatively few studies that deal with the investigation of blockage constraints present in the confined cylinder problem under varying thermal buoyancy. The aim of the present