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Particle image velocimetry measurements for opposing flow in a vertical channel with a differential and asymmetric heating condition

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Abstract

Particle image velocimetry (PIV) measurements were carried out in an experimental investigation of laminar mixed convection in a vertical duct with a square cross-section. The main downward water-flow is driven by gravity while a portion of a lateral side is heated, and buoyancy forces produce non-stationary vortex structures close to the heated region. Various ranges of the Grashof number, *Gr* are studied in combination with the Reynolds number, *Re* varying from 300 to 700. The values of the generalized buoyancy parameter or Richardson number, $Ri = Gr/Re^2$ parallel to the Grashof number are included in the results. The influence of these nondimensional parameters and how they affect the fluid flow structure and vortex sizes and locations are reported. The flow patterns are nonsymmetric, periodic, and exhibit increasing complexity and frequency for increasing buoyancy. For the averaged values of the resulting vortex dimensions, it was found that a better and more congruent representation occurs when employing the Grashof and Reynolds numbers as independent parameters.

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Keywords: Mixed convection; Opposed flows; PIV; Unsteady convective flows

1. Introduction

Buoyant effects in fluid flow in channels have been studied extensively due to its practical applications including the design of compact heat exchangers, solar collectors, nuclear reactors and the cooling of electronic equipment. The subject of forced and mixed convection in rectangular ducts with uniform heating conditions has been widely treated in the literature, as can be seen in the review on this subject by Hartnett and Kostic [1]. Thermal buoyancy forces play a significant role in forced convection heat transfer when the flow velocity is relatively small and the temperature difference between the surface and the free stream is relatively large. The thermal buoyancy force may be either assisting or opposing the forced flow, depending on the forced flow direction relative to gravity and the heating/cooling conditions. Mixed convection is in general a multi-parametric process. Together with the geometrical parameters arising in any specific problem, there are three important parameters. The Reynolds (*Re*), Grashof (*Gr*) and Prandtl (*Pr*) numbers characterize the forced flow and the influence of buoyancy. However, depending on the specific problem studied, instead of using the Reynolds and Grashof numbers as independent parameters, a combination of the form Gr/Re^n is frequently employed in addition to the Reynolds number. The value of $n = 2$ is used by simple reasons. The order of magnitude

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