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Flow field and heat transfer on the base surface of a finite circular cylinder in crossflow

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This work deals with an experimental analysis of the flow field downstream of a finite circular cylinder and of the convective heat transfer coefficient over the wall the cylinder is mounted on. The influence of the cylinder aspect ratio *AR* and of the Reynolds number *Re* are investigated. Heat transfer measurements are performed by using infrared thermography along with the *heated thin foil* heat flux sensor, at four values of *Re* (4,000, 8,000, 16,000 and 32,000) and four values of *AR* (1, 2, 4 and 8), while flow field measurements are carried out in the cylinder wake at $Re = 16{,}000$ by means of PIV and Stereo PIV for $AR = 2$ and 8. The average flow field and the coherent structures are investigated in order to understand their influence on the heat transfer topology and enhancement. Some correlations for the heat transfer enhancement are also presented.

1. Introduction

Many authors study the flow field around a circular cylinder in a cross flow which is a classical topic of blunt bodies aerodynamics. Both the instantaneous and the phase averaged flow fields of the infinite (2D) cylinder wake are widely investigated with different techniques, e.g., Hot Wire and Particle Image Velocimetry (PIV) [1–3]. In particular, Williamson [3] shows 8 vortex shedding regimes, depending on the Reynolds number (*Re*). The regime of the present interest is the Shear–Layer Transition Regime, valid for *Re* ranging between 1000 and 200,000. In this regime, the Kelvin-Helmholtz instabilities, related to the separation of the shear layers from the body sides, strongly interact with the vortex shedding.

Strictly speaking, most of cylinder wakes have 3D unsteady flow features and require a 3D analysis [4]. Frequently, the cylinder is not infinitely long, or enclosed between end-plates, but may have one free end the fluid is flowing over. Examples of such geometry are buildings, parts of electronic components, automotive engine parts or turbulence promoters. Three dimensional features of the mean flow really arise when the cylinder aspect ratio is small and/or at the cylinder free end: the latter causing changes in the vortex formation length as well as the vortex shedding pattern. Budair et al. [5] investigate the wake of a finite cylinder with $Re = 15{,}000$ and find the vortex shedding disappearance for an aspect ratio lower than 7. Other investigators [6,7] experimentally study the wake of four circular cylinders (aspect ratios $AR = 9$, 7, 5, and 3) mounted normally to a wall at a Reynolds number of 60,000: in all the cases a similar turbulent wake structure is found for cylinders of $AR = 9$, 7, and 5, while a distinctly different structure is found for the $AR = 3$ cylinder. According to Kawamura et al. [8], for relatively high aspect ratios, the vortex shedding frequency may vary in a cellular manner along the cylinder height and each cell has a different frequency (or Strouhal number), whereas the vortex shedding is suppressed near the free end and near the cylinder base as sketched in Fig. 1.

The study of convective heat transfer on a wall, with a cylinder protruding from it, is interesting for its several applications such as the cooling of automotive engine parts and of electronic components. The heat transfer enhancement obtained with a protruding element from a plane surface is quite known and many experimental analyses are performed for rows or arrays of cylinders [9–11]. Despite that, the available literature on the heat transfer due to a finite aspect-ratio circular cylinder is rather limited.

With the naphthalene sublimation technique, Goldstein et al. [12] study the effects on the mass transfer of a horseshoe vortex flow around a circular cylinder, protruding from a flat surface and exposed to a uniform free stream. Two different cylinder heights

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