Computers & Fluids 109 (2015) 155–167

Contents lists available at ScienceDirect

Computers & Fluids

journal homepage: www.elsevier.com/locate/compfluid

Control of fluid flow and heat transfer around a square cylinder by uniform suction and blowing at low Reynolds numbers

A. Sohankar [a,*], M. Khodadadi [b], E. Rangraz [b]

[a] Department of Mechanical Engineering, Isfahan University of Technology, Isfahan, Iran
[b] Department of Mechanical Engineering, Yazd University, Yazd, Iran

ARTICLE INFO

Article history:
Received 31 March 2014
Received in revised form 16 November 2014
Accepted 23 December 2014
Available online 30 December 2014

Keywords:
Active control
Suction/blowing
Heat transfer
Square cylinder
Vortex shedding
Force reduction

ABSTRACT

The effects of uniform suction and blowing through the surfaces of a square cylinder on the vortex shedding, wake flow and heat transfer are investigated, $Re = 70–150$, $Pr = 0.7$. All numerical simulations are performed with a finite-volume code based on a collocated grid arrangement. To find the optimum condition, where vortex shedding suppression occurs and the maximum reductions on the forces and their fluctuations provide, three simple cases are examined. In these cases, the influence of the uniform blowing and suction only through the front surface (case I), rear surface (case II) and top/bottom surface (case III) is studied at $Re = 150$. Based on the obtained advantages of these simple cases, different combinations of the suction and blowing on the cylinder sides are considered and an optimum case is introduced. In this case, suction is applied on the top and bottom surfaces and blowing is employed on the front and rear faces. The effect of the Reynolds number on the results for the optimum configuration is also investigated ($Re = 70$, 100, 150). This study shows that the lift and drag fluctuations for the optimum configuration decay and the maximum reduction on the drag force are 61%, 67% and 72% for $Re = 70$, 100, 150, respectively. An optimum case with respect to heat transfer is also introduced where suction is applied through all surfaces.

1. Introduction

Flow-induced vibrations and generation of the fluctuating forces are major problems in most of the flow systems in engineering and industrial applications. If this phenomena is not considered in design of an engineering structure, it can demolish the structure due to oscillations. The structure of the wake region and the shape of vortex formation are main factors for the value of the fluctuating forces exerting on the structures. Thus, the elimination or reduction of the fluctuating forces and vortex shedding from such bodies by the application of the various passive or active flow-control methods is necessary. Passive flow control methods require no external energy input, typically changing the geometrical configurations such as splitter plate, small control cylinder, trip wire or a grooved wall, change of surface roughness, adding fixed mechanical vortex disturbers, ribs or large eddy breakup devices on to the main body to influence vortex shedding [1–7]. Active flow control methods require an energy input. Solid wall motion, blowing or suction from a surface, the injection of micro bubbles or particles, acoustic excitation, periodic rotation or oscillation of a body, and electromagnetic forces can be given as examples to active control methods. These methods due to kinds of energy that is used divided to three kinds: (1) Actuators (electromagnetic, acoustic forcing, etc.), (2) motion of the solid wall (forced cylinder vibrations) and (3) generate secondary flow (suction, blowing, bleed) [8–11].

A limited number of literatures have been published reporting the effects of injection or suction through a bluff body on the aerodynamics parameters and heat transfer characteristics. Mathelin et al. [12] numerically studied the flow around a porous circular cylinder in a cross-flow when complete blowing was applied through the cylinder at Reynolds number range of $3900 < Re < 31{,}000$. They revealed that the pressure defect at the rear of the circular cylinder tended to “fill up” with blowing, leading to lower transverse static pressure gradients in the near wake. Fransson et al. [10] conducted experiments on the flow around a porous circular cylinder subject to continuous suction or blowing at the range of Reynolds numbers of $8.5–25 \times 10^3$. Their results show that the drag coefficient of the cylinder increases linearly with the blowing rate, whereas for suction there is a drastic decrease at a specific rate. Also, it was observed that the Strouhal number decreases with blowing and increases with suction.

* Corresponding author.
E-mail address: asohankar@cc.iut.ac.ir (A. Sohankar).

http://dx.doi.org/10.1016/j.compfluid.2014.12.020
0045-7930/