Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Journal of Electrostatics 64 (2006) 569–573
Journal of ELECTROSTATICS
www.elsevier.com/locate/elstat

On-set of EHD turbulence for cylinder in cross flow under corona discharges

J.S. Chang[a,*], D. Brocilo[a], K. Urashima[a], J. Dekowski[b], J. Podlinski[b], J. Mizeraczyk[b], G. Touchard[c]

[a]*Department of Engineering Physics, McMaster University, Hamilton, Ontario, Canada L8S 4L7*
[b]*Institute for Fluid Flow Machinery, Polish Academy of Sciences, Gdansk, Poland*
[c]*LEA, University of Poitiers, Poitiers, France*

Available online 28 November 2005

Abstract

Experimental and theoretical investigations have been conducted for the on-set of electrohydrodynamically (EHD) induced turbulence for cylinder in cross flow. The experiments were conducted for Reynolds numbers from 0.2 to 80 based on cylinder diameters, and Reynolds numbers from 10^3 to 4×10^3 based on the flow channel width. This flow conditions represent laminar to transitional-flow before the on-set of the EHD-turbulent flow. Theoretical analysis was based on the mass, momentum, and charged particle conservation equations coupled with the Poisson's equation for electric field evaluation. The results showed that: (1) on-set of EHD turbulence is initiated near the real-stagnation point; (2) EHD turbulence can be generated even for Reynolds numbers (Re) less than 0.2, if the EHD number (Ehd) is larger than the critical Reynolds number square (Ehd $> Re^2$); and (3) the electrical origin of instability, which is leading into the on-set of turbulence can be estimated from Ehd/Db$^2 > Re^2$ relation, where Db is the Debye number.

Keywords: Electrohydrodynamics; Corona; Turbulence

1. Introduction

Based on the previous experimental and theoretical work of cylinder in cross flow [1–3], flow profiles have been determined and correlated to the magnitude of the Reynolds number ($Re_{cd} = U_o L/\nu_f$), where U_o is the mean velocity far upstream of the cylinder, L is the characteristic dimension either the cylinder diameter or channel width, and ν_f is the kinematic viscosity of fluid. The results show that the flow past cylinder can be categorized in six regimes as follows: (a) For a very small Reynolds numbers ($Re < 0.1$), symmetrical flow resembling non-viscous fluid flow has been observed; (b) for Reynolds numbers in the range from 0.1 to 7 ($0.1 < Re < 7$), the streamlines are not symmetrical before or after the cylinder; (c) for $7 < Re < 80$, the recirculation wake appears in a downstream region in the form of two symmetrical vortices; (d) for $80 < Re < 300$, the flow becomes unstable and laminar; (e) for larger Reynolds numbers, the flow becomes more unstable and the well-known Von Karman vortex appears. The on-set of turbulence occurs at $Re \geqslant 5 \times 10^5$.

It is well known that a space charge gradient coupled with an electric field induces instabilities leading to a fluid motion [4–7]. When the fluid is a gas, it has been observed, both theoretically and experimentally [8–10] that the electrical charges generated by corona discharge together with the electric field will generate motion of the gas, known as electrohydrodynamically (EHD) induced secondary flow or ionic wind. This type of flow can be used not only for pressure drop control in a flow channel but also for the enhancement of mass and heat transfer. Under these EHD flow, transition from laminar to turbulent flow onsets when the space charge injection exceeds the threshold value. In this paper, experimental and theoretical investigations were conducted to study the mechanisms of

*Corresponding author. Fax: +1 905 527 5222.
E-mail address: changj@mcmaster.ca (J.S. Chang).

0304-3886/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.elstat.2005.10.035