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HOPF BIFURCATION, VORTEX SHEDDING AND NEAR WAKE STUDY OF A HEATED CYLINDER IN CROSS FLOW*

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Abstract– The wake flow and the onset of Karman-vortex shedding corresponding to periodic forces of a heated circular cylinder are investigated numerically with a SIMPLEC finite volume code. This study is performed for Reynolds numbers ranging from 20 to 200 and a Prandtl number of 0.7.

The first bifurcation of flow over bluff bodies, which is strictly a Hopf type, is modelled using the Stuart-Landau equation. In this study, it is shown that the flow behind a circular cylinder is steady up to Re=49 and beyond this critical value, the flow develops to a periodic state, corresponding to the vortex shedding and force oscillation on the body. The wake structure is studied close to the oscillation threshold and also at the higher Reynolds numbers using streamlines, pressure, temperature, Nusselt numbers and wall vorticity profiles and iso-lines. Some useful physical quantities, such as time mean separation angle, Nusselt number, the dominating wake frequency (Strouhal and Roshko numbers), mean drag and the RMS value of lift are computed and compared with numerical and experimental results. Based on the results of this study, the empirical relations for the Reynolds dependence of the mean Nusselt number, mean separation angle, Strouhal and Roshko numbers are obtained.

Keywords– Vortex shedding, Hopf bifurcation, heated cylinder, stuart-landau equation, strouhal number, Roshko number, Reynolds number

1. INTRODUCTION

Convective heat transfer between fluid and bluff bodies such as circular cylinders arise in numerous industrial applications like tubular heat exchangers, nuclear reactor fuel rods, boilers, cooling of electronic equipment, chimneys, hot wire anemometry, etc. In spite of the relatively simple geometry of bluff bodies, the flow around these bodies is a complicated flow phenomenon, which has proved a challenging area for researchers in recent years. However, it was not until 1878, when Strouhal published his pioneer paper on singing wires caused by vortex shedding, that this type of flow became a subject of quantitative research. In general, the flow around bluff bodies contains many complex phenomena. The near wake of a bluff body is involved in the interactions between an attached shear layer on the frontal part of the body, the separating free shear layers springing from the sides of the body, and a massive wake flow downstream of the body, each with different and perhaps even coupled processes of developing instabilities as the Reynolds number is increased. Flow structures over these bodies change as the Reynolds number increases (Re). At Reynolds numbers below unity, the flow is fully attached with no separation. As Re is increased, the flow separates and a pair of steady symmetric vortices forms behind the body (Re ≈ 3.2-5 [1]). At higher Reynolds numbers, the vortex length of the re-circulation region behind the body grows as the Reynolds number increases. At a critical onset Reynolds number, Re_{cr1}, the twin-vortex arrangement becomes unstable, and a periodic oscillation wake and a staggered vortex street are

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