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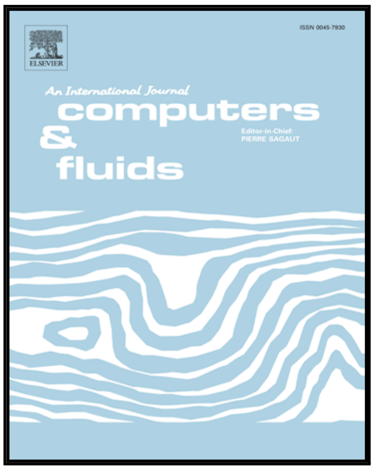

Steady flow around an inclined torus at low Reynolds numbers: Lift and drag coefficients

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Steady flow around an inclined torus at low Reynolds numbers: Lift and drag coefficients

Yu Peng[1], Ruixin Lu[1], Wei He[1,2], Larry K.B. Li[2]

Abstract

The steady flow around an inclined torus has received little attention, despite being relevant to many engineering and biological processes, such as the sedimentation of fluidized particles and the motion of natural micro-swimmers. In this study, we perform three-dimensional direct numerical simulations of the flow around an inclined torus over a range of aspect ratios ($2 \leqslant Æ \leqslant 3$), inclination angles ($0 \leqslant \theta \leqslant 90°$) and Reynolds numbers ($10 \leqslant Re \leqslant 50$), with a focus on the steady flow regime preceding the onset of vortex shedding.

For a fixed Re, we find that as the torus inclines from a flow-normal orientation ($\theta = 0°$) to a flow-parallel orientation ($\theta = 90°$), the drag coefficient (C_D) decreases monotonically, while the lift coefficient (C_L) first increases from zero, reaches a maximum at $40° \leqslant \theta \leqslant 50°$ and then returns to zero owing to top-down symmetry at full inclination. The decrease in C_D with θ is caused by a decrease in the pressure drag, with almost no change in the viscous drag. The variation in C_L with θ is caused by the pressure lift dominating the viscous lift. With increasing Re, the overall trends in C_D and C_L remain qualitatively unchanged but their quantitative values decrease. Compared with the effects of θ and Re, those of $Æ$ are relatively weak for the specific flow conditions examined here. We conclude by performing a nonlinear regression analysis to generate curve fits for C_D and C_L in terms of $Æ$, θ and Re.

Keywords: Wakes, bluff-body flows, torus, recirculation zone, direct numerical simulations

1. Introduction

The flow around three-dimensional (3D) bluff bodies has been the subject of decades of analytical, numerical and experimental research [1]. However, these flows continue to attract attention owing to their significance in a wide range of established and emerging fields, such as the sedimentation of fluidized particles and fibers [2] and the active control of flow instabilities [3]. Two of the most widely studied wake flows are those from a circular cylinder [4] and from a sphere [5]. However, the flow around a torus, which is the geometrical intermediate between a cylinder and a sphere, has been less well studied, despite being

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