論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	LES Study of Aerodynamics of Two-dimensional Bluff Bodies in Crossflow at Very High Reynolds Numbers
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出典(和文)	学位:博士（工学）, 学位授与機関:東京工業大学, 報告番号:甲第10375号, 授与年月日:2016年12月31日, 学位の種別:課程博士, 審査員:田村 哲郎,喜々津 仁密,山中 浩明,肖 鋒,淺輪 貴史,大風 翼
Citation(English)	Degree:, Conferring organization: Tokyo Institute of Technology, Report number:甲第10375号, Conferred date:2016/12/31, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	環境理工学創造　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　工学　）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The thesis entitled "LES study of aerodynamics of two-dimensional bluff bodies in crossflow at very high Reynolds numbers" is composed of the following seven chapters.

Chapter 1 gives the general introduction. To reduce potential wind damages to bridge cables and high-rise buildings, the aerodynamics of typical two-dimensional bluff bodies are focused, e.g., circular and square cylinders. The knowledge of aerodynamic features at real Reynolds numbers (Re) encountered by structures is required in comparison with an amount of previous research interest at lower Re regimes. Considering the feasibility of large-eddy simulation (LES), this dissertation aims to clarify the aerodynamics of two-dimensional bluff bodies at very high Res which are close to the reality of structures.

Chapter 2 outlines the details of numerical methods that will be applied to simulate bluff bodies flow fields. The filtered governing equations of LES are presented based both on the Cartesian and generalized curvilinear coordinates. The introduction of LES models is followed, including the eddy-viscosity approximation, scale-similarity and mixed model. Meanwhile, the discretization methods in space and time are summarized for both finite volume method and finite difference method. Finally, the parallel computation technique is discussed which serves the very-high-Re flow simulations.

Chapter 3 presents the validation testing of above numerical methods based on the unsteady flows around a square cylinder at high subcritical Res. In addition to the conventional structured grids, the unstructured-grid LES is examined systematically in terms of numerical schemes for the convective term, meshing strategies and spanwise lengths. On the whole, LES based on both grid systems are able to provide fairly accurate prediction of time-averaged and r.m.s quantities. The appropriate numerical schemes are suggested. The mesh refinement in wake turns out a good solution to improve the far-wake velocity distribution and to overcome the earlier energy decay of small-scale turbulent motions caused by artificial dissipation. It is suggested for the subcritical flow simulations with strongly vigorous vortex shedding. Moreover, the spanwise length is found to be of great importance in obtaining reasonable spanwise correlation of pressure and consequently the overall fluctuating lift force.

On the basis of the above, Chapter 4 investigates the aerodynamics of circular cylinders at upper subcritical Res which correspond to the Re when wind-induced vibrations of long-span bridge cables happen in reality. With a focus on vortex shedding, the unstructured-grid LES is utilized when the wake is specially refined. It is found that even at such high Res, a three-dimensional pattern of vortical filed is also present in the wake with a large phase lag in primary vortex shedding. The three-dimensional patterns result in total force modulation and weak spanwise correlation. The development process of three-dimensional wakes starts from local phase

variations in Karman vortex shedding, which are induced by the “irregular” streamwise vortex. The following wake is associated with a successive evolution composed of certain stages in order. Moreover, such three-dimensional pattern also weakens vortex shedding in cross sections perpendicular to the cylinder axis, leading to modulation of sectional lifts.

Chapter 5 presents a systematical investigation into the supercritical flows and their effects on a rounded-corner square cylinder in light of increasing applications of corner modification to high-rise buildings. The structured-grid LES with the dynamic mixed model is demonstrated to predict accurately supercritical flows past a bluff body. Results show that strong Re effects exist even for the rounded-corner square cylinder, i.e., the aerodynamic characteristics at supercritical Res behave much differently from those at subcritical Res. The mechanism is explained by the different-Re flows. At supercritical Res, overall free stream flows along the shape of cylinder cross sections, finally separates from the leeward corners and generates the primary vortex behind the cylinder, resulting in a much smaller recirculation region in the wake. Furthermore, it is found that the attached flow on side faces is composed of the turbulent boundary layer under pressure gradients which varies periodically with primary vortex shedding.

Chapter 6 explores the effects of strongly shear inflow on the aerodynamic behavior of the rounded-corner square cylinder at subcritical and supercritical Res from the practical viewpoint. It is founded that the shear inflows have different effects varied by Res. At subcritical Res, the asymmetry of flow is observed on both cylinder sides. The shear layer on the high-velocity side becomes closer to (or reattaches to) the upper wall while that on the other side is spaced farther from the wall, inducing the asymmetric pressure distributions and consequently the lift acting from the low-velocity side to the high-velocity side. In comparison, the supercritical flows seem not to be greatly affected by the shear inflow, including the attached flow on side walls and the vortex shedding behind the cylinder. As a result, the shapes of pressure distributions remain nearly unchanged and the time-averaged lift is still close to zero.

Finally Chapter 7 concludes the whole dissertation. It summarizes the findings of each chapter and also points out the limitation and further work.