Preface

Flow control is one of the frontier subjects in fluid mechanics and aerodynamics. It attempts to introduce perturbations into the flow field to alter the original flow development path into an ideal state, and thus to achieve the desired goals, such as lift enhancement drag reduction, vibration suppression, noise reduction, fuel and heat transfer enhancement, etc. There are many different kinds of flow control techniques, which could be classified into passive control and active control based on energy input. Passive control needs no energy and it is easy to implement. It could be further distinguished as the fundamental techniques that are developed based on our understanding of flow physics, and the biomimetic techniques which are derived from nature. Active control needs extra energy, and can be adjusted during the control process and thus be implemented in real-time and unsteady flow control. Thus, control effectiveness and efficiency for the active techniques is usually more significant than that for passive ones.

Flow control has developed in association with the development of the aviation industry. In particular, it has made great contributions to the advancement of aviation. Some control techniques have been used in aircraft up to now, such as high-lift airfoils, vortex generators, wing tips, etc. Flow control could also be widely used in space, turbomachinery, combustion, building, transportation, etc. Implementation of flow control is usually related to complex flow phenomena. Thus, flow control is of great significance for not only the development of the subject of fluid mechanics but also has great potential applications in engineering.

The primary focus of this book is to introduce the most important and typical flow control techniques. Chapter 1 offers a general introduction to flow control, including the background, classification, and features of various passive and active techniques. Then, each chapter will mainly discuss one typical control method, including its fundamental characteristics, applications in various fields and control mechanisms. The book is organized in this way to enable readers to better understand and master flow control.

Chapter 2 introduces the Gurney flap, which is a small device attached to the pressure surface of the airfoil to effectively increase the lift coefficient. Chapter 3 introduces the vortex generator, which is a simple device to induce streamwise vortex for separation control, thus to reduce the pressure-difference drag. Chapter 4 introduces roughness, which could be used to delay flow transition and influence the coherent structures in the turbulent boundary layer, thus to reduce friction drag. Chapter 5 introduces polymer, which is also an effective control approach for turbulent drag reduction.

Chapter 6 introduces biological control techniques, where four of them are presented. Hairy coating helps to reduce flow separation, and the leading-edge tubercles on the wing improve the aerodynamic performance at high angles of attack. The riblets on a flat plate contribute to a reduction in the friction drag, while the grooves on a bluff body can reduce lift fluctuation.

Chapter 7 introduces the jet, which can enhance momentum mixing between inner and outer boundary layer, thus to delay or eliminate flow separation. In addition to its conventional applications, some novel control approaches are also introduced, such as circulation control, jet vortex generator, and jet Gurney flap. Chapter 8 introduces the synthetic jet, which combines the blowing and suction to induce vortical structures periodically for flow control. The synthetic jet is found to be more efficient than the jet, and thus shows great potential for application in various engineering fields.

Chapter 9 introduces the plasma actuator, which is a technique based on electronics. The features and applications of various plasma actuators are presented. In particular, some novel control conceptions combining the characteristics of the DBD plasma actuator and conventional techniques are presented, including the plasma synthetic jet, the plasma Gurney flap, plasma circulation control, and the plasma vortex generator. Chapter 10 introduces Lorentz force, which is a technique based on electromagnetism. The uses of streamwise and spanwise Lorentz forces for the control of boundary layer and flow around airfoils and bluff bodies are presented. Chapter 11 introduces closed-loop control, which is a method of controlling active techniques. The main ideas of closed-loop control and some control examples based on the reduced-order model and measured variables are presented.

This book could be developed for courses aimed at postgraduate students in subjects of fluid mechanics, aerodynamics, aviation propulsion, fluid machinery, aircraft design, and wind engineering. It is also useful for researchers and engineers involved in the related fields.

Although this book has only two authors, it represents the efforts of our research group of Turbulence and Flow Control Laboratory at the Beijing University of Aeronautics and Astronautics. Zhenyao Li did the typesetting work and picture editing, and undertook the arduous task of seeking figure permissions. Liyang Liu also assisted with the picture editing. Chong Pan, Qi Gao, Guosheng He, Yang Xu, Di Wu, Yuan Qu, and Jiang-Sheng Wang put forward helpful suggestions. Lei Wang, Tuo Chen, Tingshen Liu, Guangyao Cui, and Guopeng Cui helped to prepare materials. We appreciate everyone's efforts.

The contents presented in this book are mainly based on our own research and existing literature. We have attempted to present a comprehensive introduction to the features, mechanisms, and applications of the flow control. However, we are aware that some techniques may not be covered as fully as others and some works may not be included due to our limited knowledge.