AEROSPACE RESEARCH COMMUNICATIONS
SPECIAL ISSUE EDITORIAL
published: 06 January 2025
doi: 10.3389/arc.2024.14155

Editorial: Flow Control

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Keywords: active flow control, passive flow control, drag reduction, multi-objective design, subsonic flow, supersonic flow, hypersonic flow

Editorial on the Special Issue

Flow Control

This Special Issue of Aerospace Research Communications showcases recent advances and challenges in the fundamental understanding and practical implementation of flow control techniques. Flow control is a technical means of manipulating the behaviors and characteristics of fluid flows. The ultimate goal is to enhance or modify flow properties, such as velocity, pressure, and turbulence intensity, in order to achieve specific engineering objectives. Flow control can be broadly classified into two categories: passive and active. Passive flow control is generally simpler and more cost-effective than active control, but it may have limited effectiveness and may not be suitable for all types of flows. Active flow control, while more complex and often more expensive, can achieve higher levels of flow manipulation and may be applied to a wider range of flows.

As an example of passive flow control, Yu et al. have carried out flow field analysis of a turbulent channel controlled by scalloped riblets. Riblets are small protruding surfaces along the direction of the flow, and are one of the most well-known passive turbulent drag reduction methods. The shape of a scalloped riblet is constructed by smoothly connecting two third-order polynomials and is not as sharp in the tip as corresponding triangular riblets with the same height-width ratio. Numerical simulations have been performed for turbulent channel flow with and without riblet control. It should be noted that the class of scalloped riblets discussed in this article is suitable for investigations on the influences of curvatures at the tip and the valley of the riblet in future.

As an example of active flow control, Huang et al. have investigated the Reynolds number effects on the drag reduction with a spanwise traveling wave of blowing and suction in turbulent channel flows. Turbulent channel flows with $Re\tau = 180$ and $Re\tau = 550$ are controlled to reduce the drag with a spanwise traveling wave of the blowing and suction method. An oscillatory spanwise motion above the wall is generated by a spanwise traveling wave with a periodically reversing propagation direction, similarly as the Stokes layer produced by the wall oscillation. Through an asymptotic expansion analysis, the authors found that the deterioration in drag reduction rates is due to the less effective lift-up effects from the actuation, less contribution from the inner layer region, and small-scale structures at a higher Reynolds number.

In general concept of enhancing wake vortex decay, Xu et al. have carried out numerical optimization on aircraft wake vortex decay enhancement. Blowing air at the end of the airport runway can accelerate the decay of the near-ground aircraft wake vortex, and thereby reducing the negative impact of the vortex on the following aircraft. However, the benefits of accelerating wake dissipation vary for different blowing parameters, so it is necessary to set appropriate parameters in order to obtain better acceleration results. Because of the high cost of traditional optimization

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Received: 03 December 2024
Accepted: 16 December 2024
Published: 06 January 2025

Citation:
Zheng Y, Fu S and Valero E (2025) Editorial: Flow Control. Aerosp. Res. Commun. 2:14155. doi: 10.3389/arc.2024.14155

methods, a Kriging surrogate model is used to obtain a better design of the blowing zone for enhancement of wake vortex decay. By overlapping and comparing the design spaces for different wake vortices, a multi-objective design is realized, which improves the engineering feasibility of the current blowing method.

As another example of active flow control, Li et al. have carried out numerical investigations of outer-layer turbulent boundary layer control for drag reduction through micro fluidic-jet actuators. The study aims to reduce turbulent drag by reshaping the flow structure within the turbulent boundary layer. To ensure the calculation accuracy of the core region and reduce the consumption of computing resources, a zonal LES/RANS strategy and WMLES method are proposed to simulate the effects of fluidic-actuators for outer-layer boundary control, in which high-performance computing has to be involved. The mechanism for drag reduction is analysed via a pre-multiplied spectral method and a parallel dynamic mode decomposition (DMD) method.

The above four articles are considered mainly for subsonic fluid dynamics. Finally, Lee et al. have provided a review article on flow control strategies for supersonic/hypersonic fluid dynamics. Supersonic and hypersonic flows have gained considerable attention in the aerospace industry in recent years. Flow control is crucial for refining the quality of these high-speed flows and improving the performance and safety of fast aircraft. The review addresses the distinctive characteristics of supersonic flows compared to low-speed flows, including phenomena such as boundary layer transition, shock waves, and sonic boom. These traits give rise to significant challenges related to drag, noise, and heat. Therefore, a review of several active and passive control strategies is provided, highlighting their significant advancements in flow transitions, reducing drag, minimizing noise, and managing heat. Furthermore, a comprehensive analysis is provided for various research methodologies used in the application of flow control engineering, including wind tunnel testing, flight testing, and fluid dynamics computation.

These five articles give an overview of the present state of flow control research, and offer insights into potential future advancements, including passive flow control and active flow control, and covering subsonic, supersonic, and hypersonic cases.

AUTHOR CONTRIBUTIONS

This editorial has been drafted by lead guest editor, YZ. He has shared it with the other guest editors. All authors contributed to the article and approved the submitted version.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

GENERATIVE AI STATEMENT

The author(s) declare that no Generative AI was used in the creation of this manuscript.