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Title

Investigation of the skin-friction drag reduction capabilities of wall-normal created plasma jets in wall-bounded turbulent flow

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Abstract

Wall-normal plasma jet flow is a technique used to reduce aerodynamic drag on the surface of a body moving through a fluid, such as an aircraft which results improvement on the fuel efficiency and speed of the vehicle. The technique involves the use of plasma discharge to generate a wall-normal jet of fluid that interacts with the flow field and modifies it in a way that reduces the skin friction drag [1]. Studies have shown that wall-normal plasma jet flow can be effective in reducing drag in various flow conditions, including turbulent boundary layers [1-3]. The effectiveness of this technique depends on several factors, such as the size and shape of the plasma actuator, the applied voltage, the frequency of the discharge, and the properties of the fluid. The plasma actuator generates a plasma discharge that creates a jet of fluid that interacts with the flow field and modifies it in a way that reduces the skin friction drag [4].

Overall, wall-normal plasma jet flow shows promise as a technique for reducing aerodynamic drag, but further research is needed to optimize its parameters and assess its long-term effectiveness in industrial applications. In this study, we investigated the effectiveness of a wall-normal plasma jet in a turbulent channel flow by applying a force to the bottom wall of the channel. Our goal was to suppress the formation or interaction of organized flow structures in the flow. This study was performed for a frictional Reynolds number of $Re_\tau = 800$. We examined the skin friction drag reduction capabilities of the wall-normal plasma jet by analyzing the applied force and no-force cases. To verify the results, we investigated changes in streak formations using tools such as two-point correlations and streamwise velocity contour plots. We also assessed the manipulation of the logarithmic layer and near-wall structures by conducting an amplitude modulation analysis, which measured the degree of interplay between these structures. Our findings suggest that wall-normal plasma jet flow has the potential to reduce skin friction drag in turbulent flow. The plasma actuator was found to suppress the formation and interaction of streamwise vortices, leading to a reduction in the intensity of streaky structures. We hope that this study will contribute to the ongoing efforts to develop more efficient and effective methods for reducing aerodynamic drag.

References

[1] Kim, J. H., Choi, H., & Kawai, S. (2013). Drag reduction in wall-bounded turbulence using wall-normal plasma actuators. Physics of Fluids, 25(4), 045108.
[2] Jiang, N., Wang, T., Zhao, Y., & Zhang, X. (2019). Recent progress in plasma-based active flow control techniques for drag reduction. Aerospace Science and Technology, 92, 231-243.
[3] Huang, Y., Wang, H., & Wu, J. M. (2017). Flow control using plasma actuators. Journal of Fluid Mechanics, 817, 1-46.
[4] Altintaş A., Davidson L. and Peng S. H., "Direct Numerical Simulation of Drag Reduction by Spanwise Oscillating Dielectric Barrier Discharge Plasma Force," Physics of Fluids, Vol. 32, No. 7, 2020, Paper 075101.