IOCB 2024 Conference
The 1st International Online Conference on Biomimetics
15–17 May 2024 | Online

Numerical simulation study of airfoil with multiple biomimetic leading-edge protuberances

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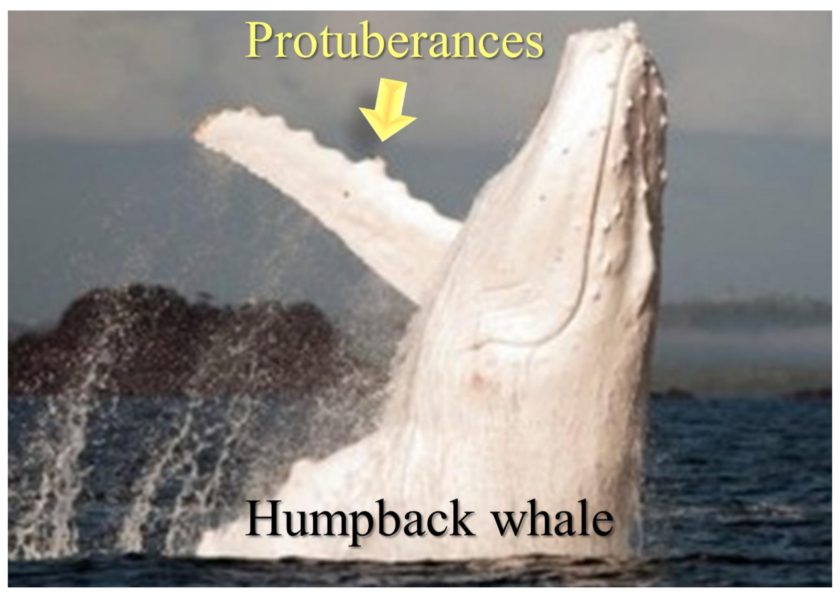
INTRODUCTION & AIM

Biomimetic leading-edge protuberances refer to a new control method that has been developed by studying humpback whales in the ocean[1]. It is a passive control method, meaning it does not require any active input or energy to function.

During the research process on this control method, researchers compared it with the studies on biomimetic airfoils conducted by Cai et al. [2] and Skillen et al.[3]. It was observed that both studies often used symmetric or periodic boundary conditions on the wings' sides. However, it was also noted that **when the wingspan width varied, it led to some interference in the calculation results**.



- **Explore** the effect of ultra wide wingspan on the performance of biomimetic airfoil
- **Explore** the changes in the flow structure of the suction surface during the process of increasing the angle of attack

Fig. 1 Leading-edge protuberances

METHOD

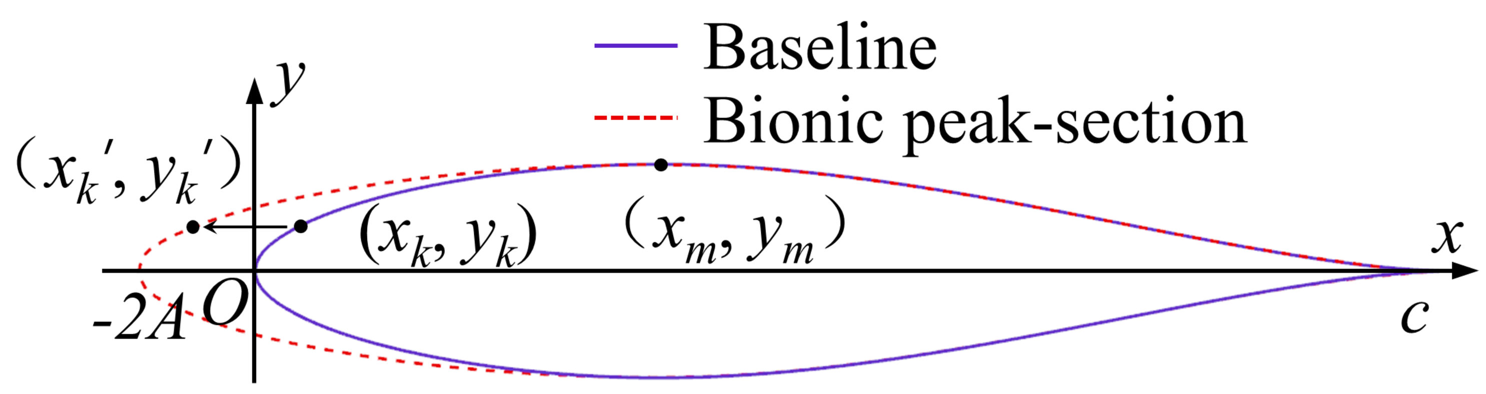


Fig. 2 Baseline airfoil and biomimetic airfoil profiles

$$\begin{cases} x_i' = \begin{cases} x_i - \dfrac{x_m - x_i}{x_m} \cdot 2A & i < m \\ x_i & i \geq m \end{cases} \\ y_i' = y_i \end{cases}$$

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$c = 0.2\text{m}$
$A = 0.05c$
$\lambda = 0.25c$
$l = 7.5c$

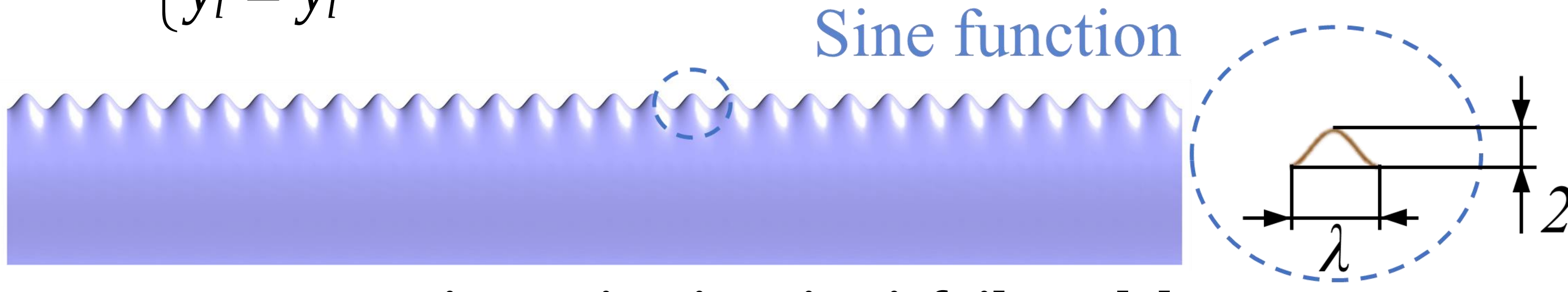

Fig. 3 Biomimetic airfoil model

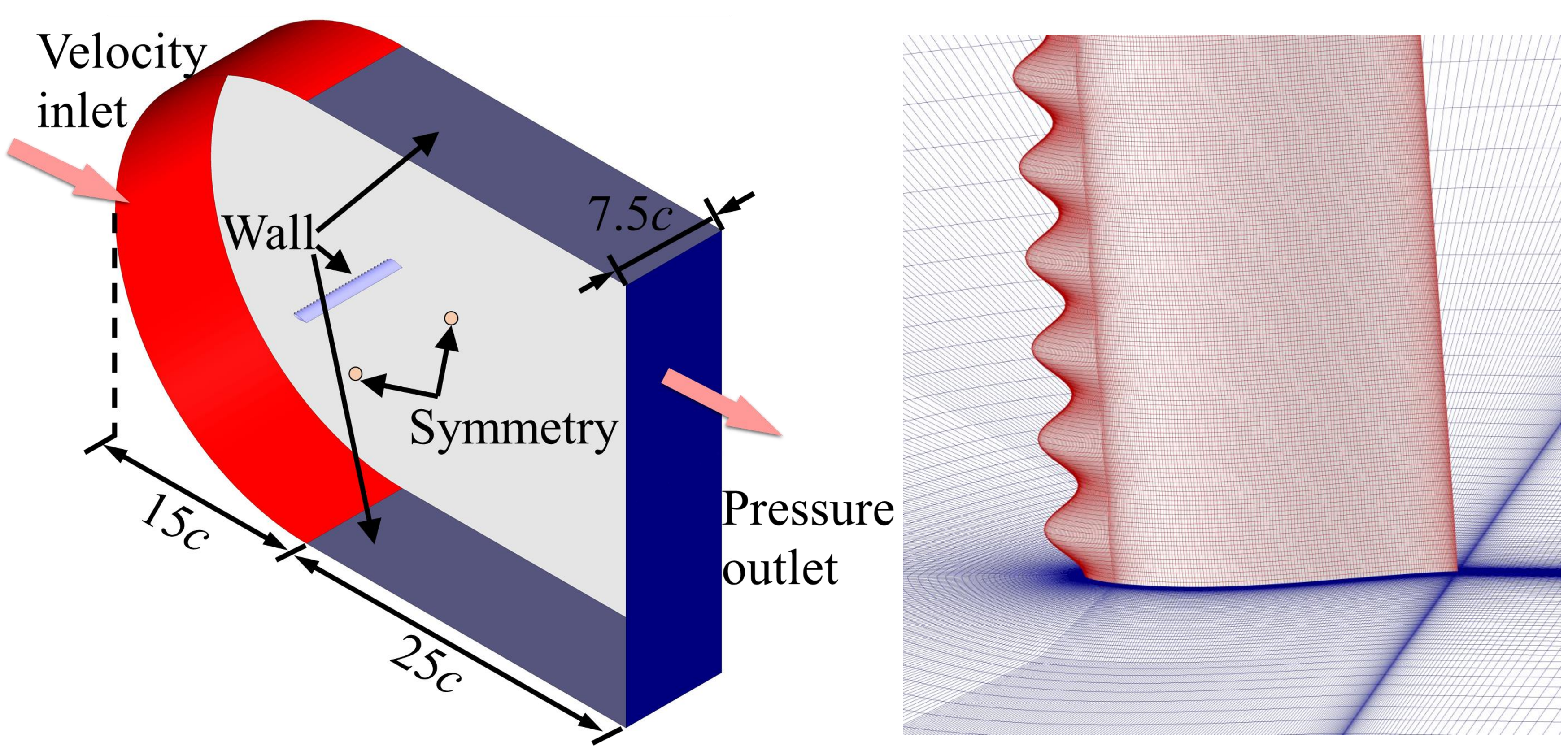

Fig. 4 Computational domain and grid

RESULTS & DISCUSSION

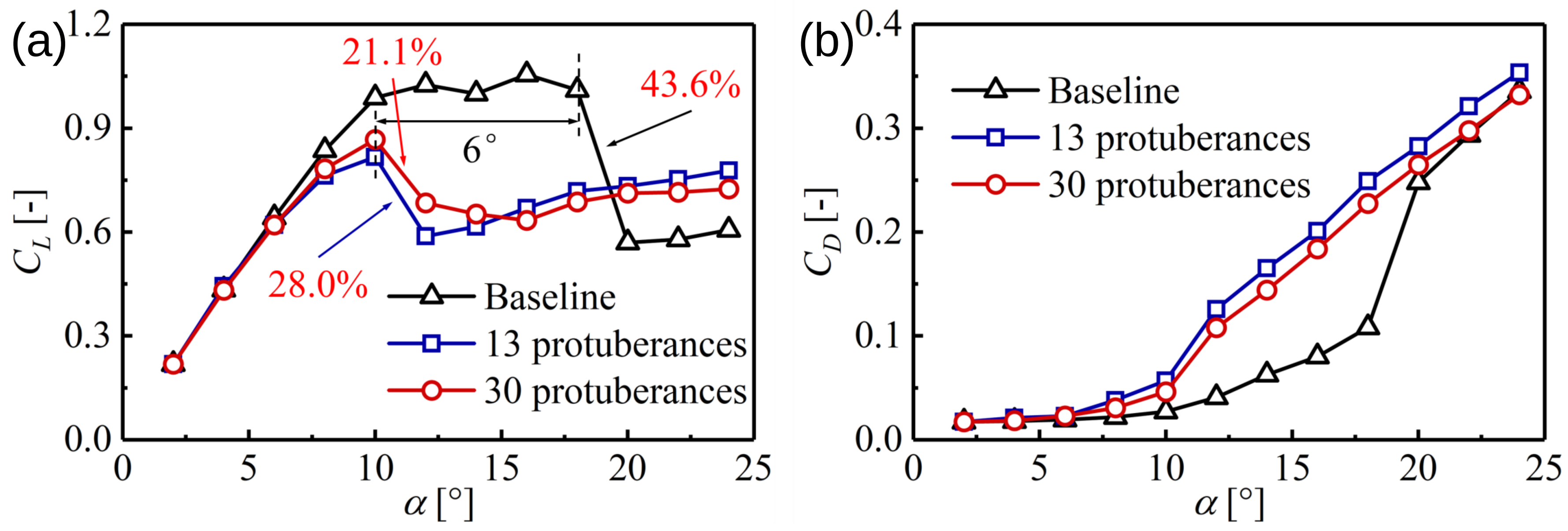

Fig. 5 Aerodynamic performance: (a) C_L, (b) C_D.

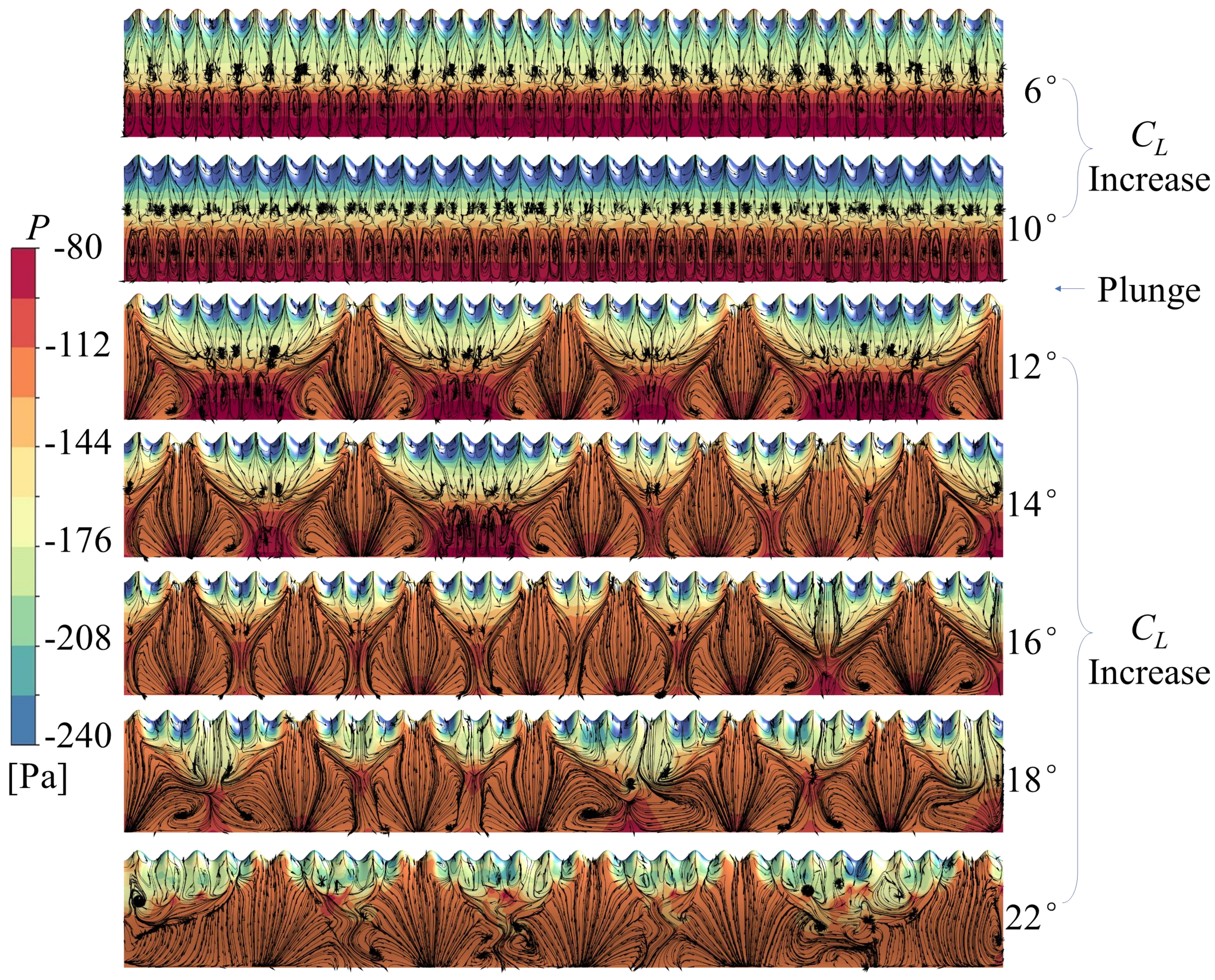

Fig. 6 Pressure and limiting streamlines

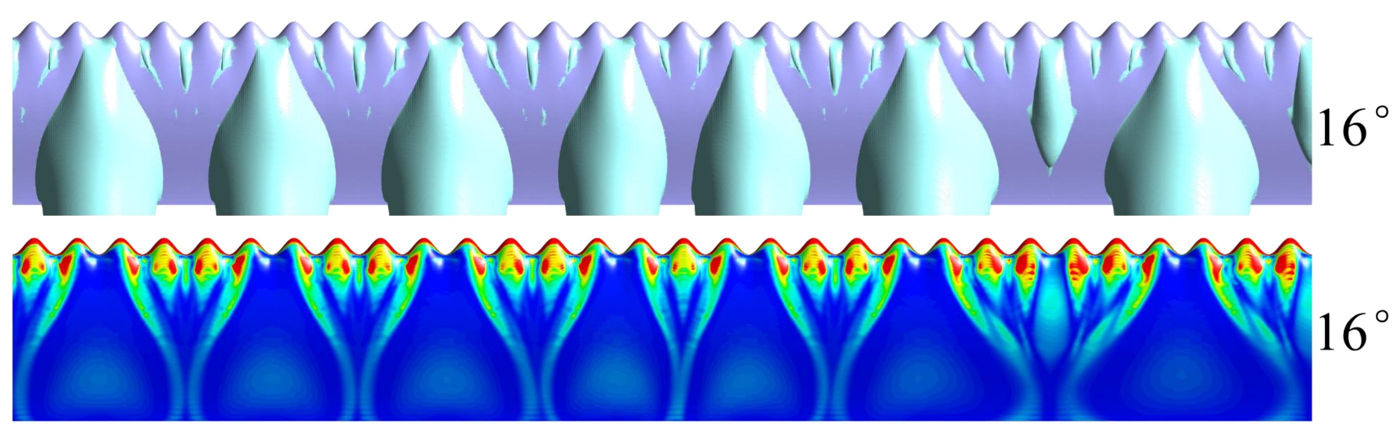

Fig. 7 V_x=0 iso-surface and V^2 distribution

CONCLUSION

The biomimetic airfoil exhibited excellent performance after stall. **The lift coefficient increased by 25.1% and the lift-to-drag ratio increased by 21.8%**. Biomimetic airfoils have advantages in working with large changes in angle of attack.

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[3] Skillen A, Revell A, et al., Flow over a wing with leading-edge undulations. AIAA Journal, 2015, 53(2): 464-472.