IOCB 2024 Conference

The 1st International Online Conference on Biomimetics

15–17 May 2024 | Online

Numerical Investigations of Cavitation Performance of the Bionic Hydrofoil with Discontinuous Leading-edge Protuberances

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INTRODUCTION & AIM

Humpback whales are a very large creature in the ocean. It was discovered that the sequential arrangement of protuberances on the leading edge of humpback flippers was the main reason for their excellent hydrodynamic performance[1], which inspired the application of protuberances to the leading edge of airfoils[2].

In this paper, the linear leading-edge of NACA 63_4-021 foil was modified, and a bionic hydrofoil with discontinuous sinusoidal leading-edge was constructed. The wavelength and amplitude were λ = 0.25C and A = 0.025C [3], respectively, and the distance between adjacent protuberances was 0.25λ. The cavitation performances of the basic hydrofoil (Basic-H) and the bionic hydrofoil (Bionic-H) were numerically studied using the large eddy simulation method and Zwart-Gerbera-Belamri cavitation model. The instantaneous flow characteristics of the hydrofoils, including lift and drag coefficients, pressure fluctuations, and cavitation evolution, were reported to explore the cavitation inhibition effect and inhibition mechanism of Bionic-H. This research provides theoretical guidance for the blade design of hydraulic machineries.

METHOD

- NACA 63_4-021
- A = 0.025C, λ = 0.25C
- L = 0.25λ

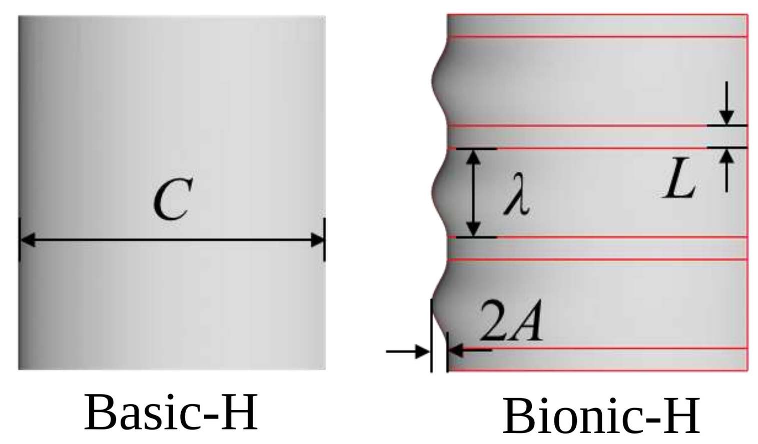


Fig.1 Model of basic hydrofoil and bionic hydrofoil

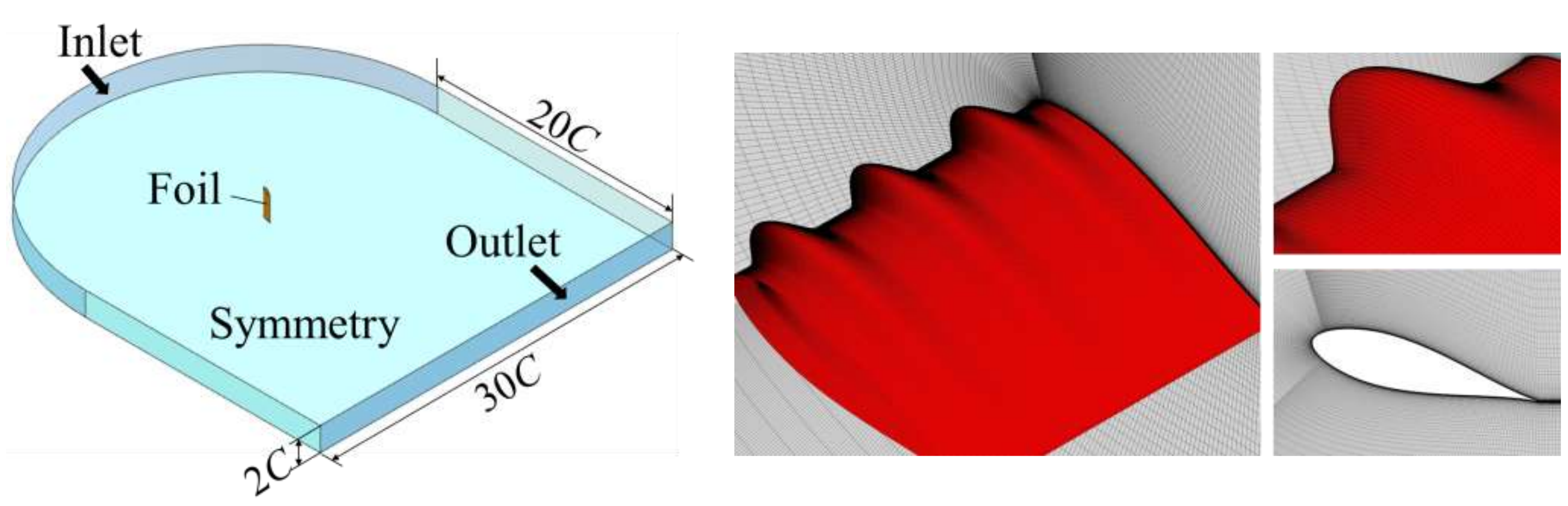


Fig.2 Model and grid of computational domain

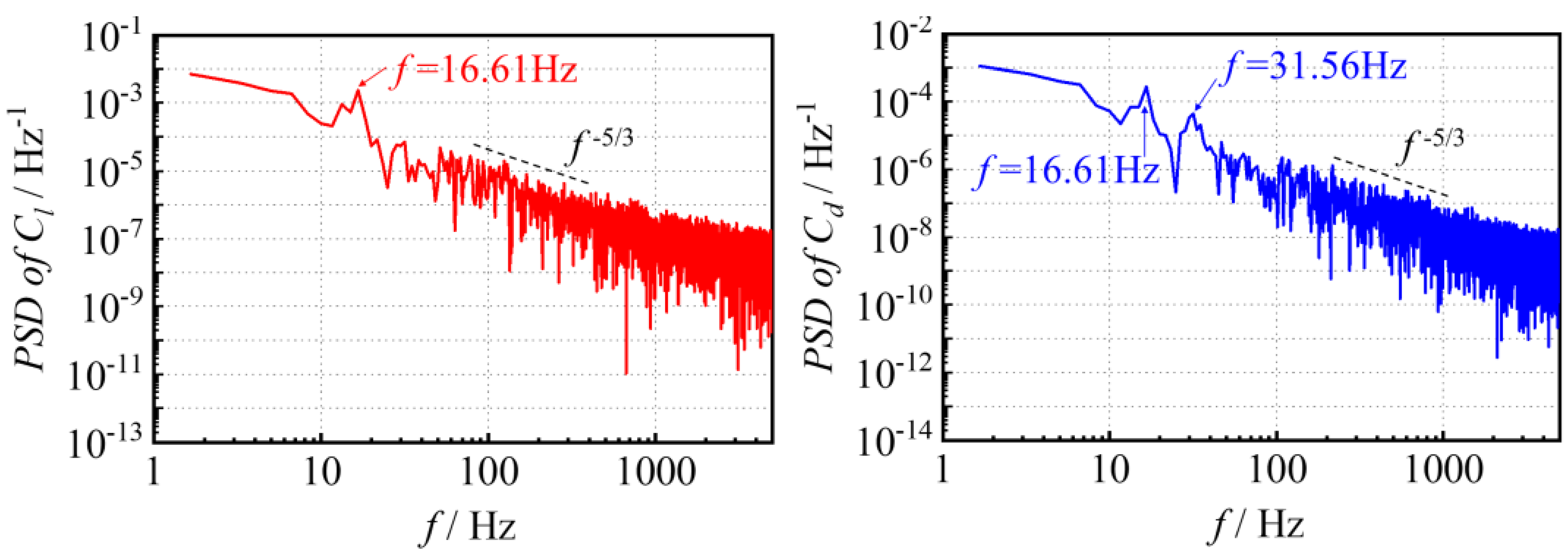


Fig.3 The power spectral density of lift and drag coefficient of the basic hydrofoil
(LES method, ZGB model, and Cavitation number of 0.8)

RESULTS & DISCUSSION

Tab.1 Time-average values of characteristic parameters

	C_l	C_d	C_l /C_d	V_b/(10^{-4}m^3)
Basic-H	0.577	0.234	2.466	1.28
Bionic-H	0.545	0.232	2.348	0.82
Comparison	-5.54%	-0.85%	-4.78%	-35.94%

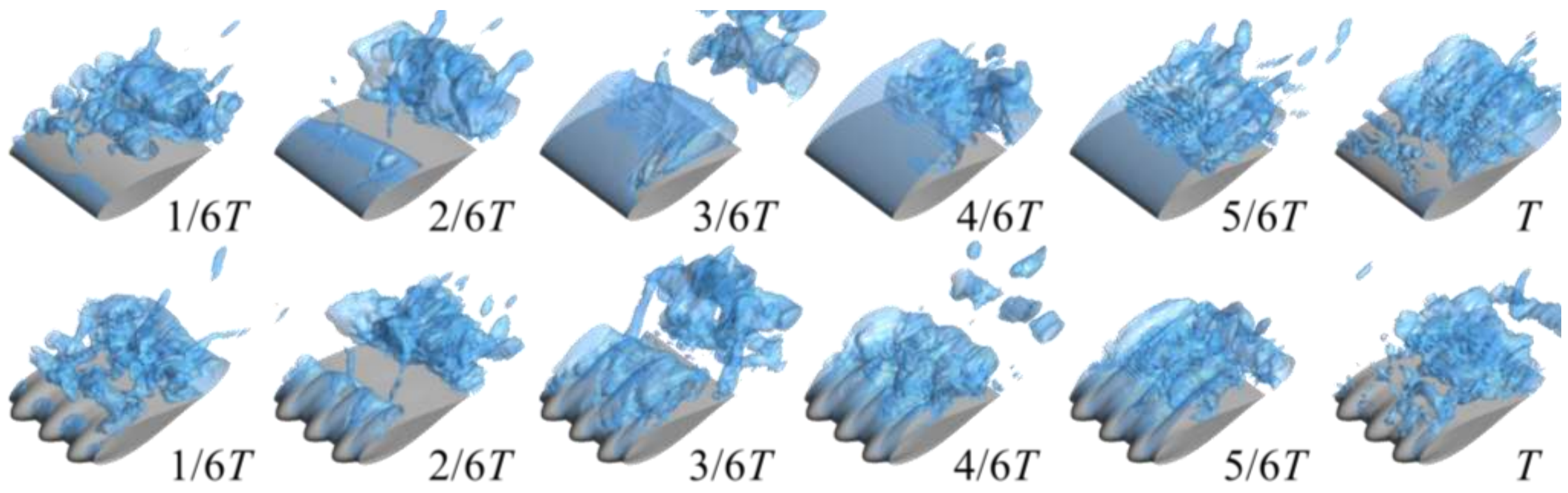


Fig.4 Cavitation development of Basic-H and Bionic-H

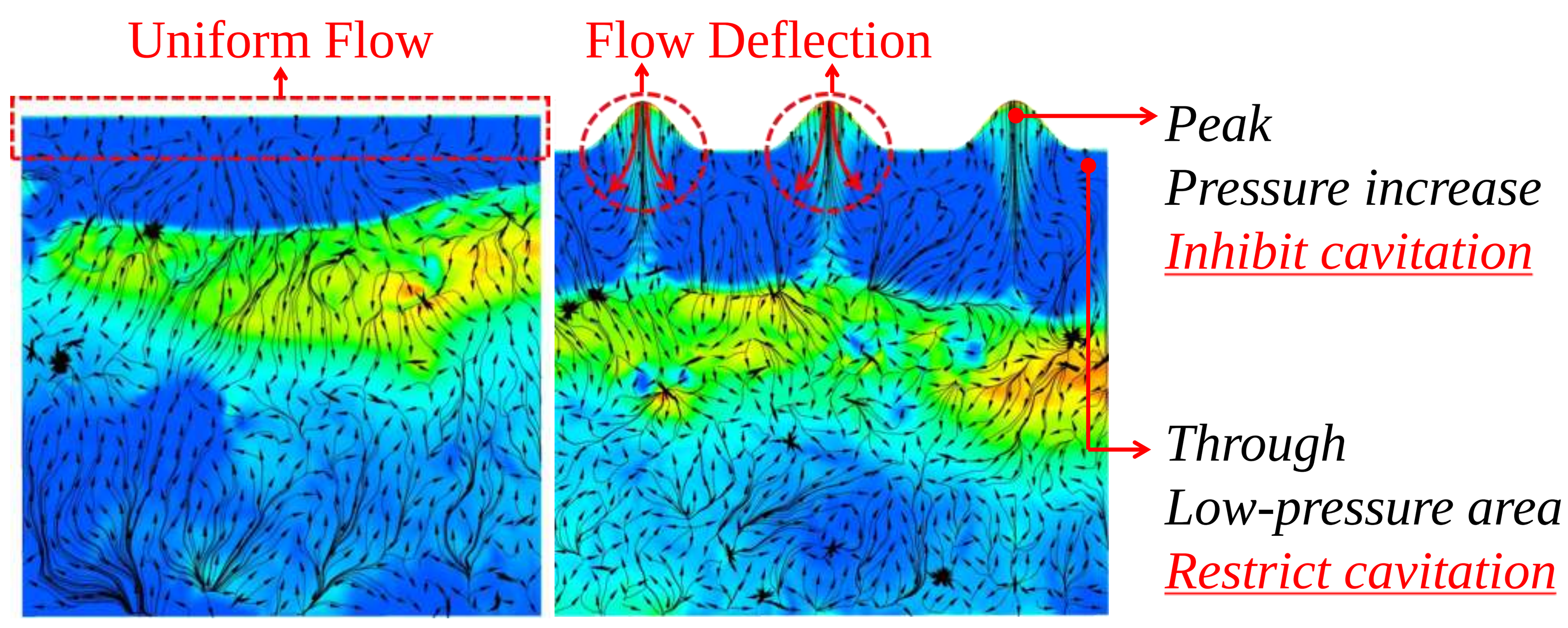
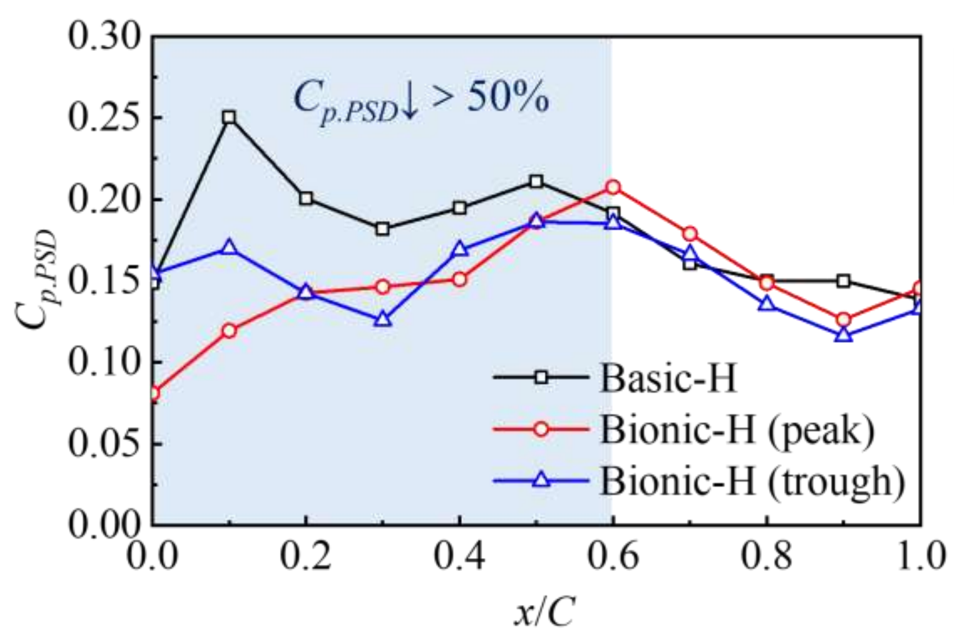


Fig.5 Pressure distribution and streamlines on the suction surface of Basic-H and Bionic-H



$$C_{p,PSD}=\sqrt{\frac{1}{N}\sum_{i=0}^{N-1}\left(C_p(t_i)-\frac{1}{N}\sum_{i=0}^{N-1}C_p(t_i)\right)^2}$$

Fig.6 Standard deviation of the pressure coefficient on suction surface

CONCLUSION

- The flow of Bionic-H shows obvious periodic patterns in the span direction, which changes the cavitation characteristics.
- The discontinuous leading-edge protuberances reduce the cavitation volume and enhance the stability of cavitation flow.

REFERENCES

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[2] Li D Y, Yang Q, Yang W Q, et al. Bionic leading-edge protuberances and hydrofoil cavitation. Physics of Fluids, 2021, 33: 93317.
[3] Custodio D, Henoch C, Johari H. Cavitation on hydrofoils with leading edge protuberances[J]. Ocean Engineering, 2018, 162: 196-208.