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Influence of Bionic Leading-edge Protuberances on a Horizontal Axis Wind Turbine

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INTRODUCTION & AIM

The operating conditions of wind turbines are changeable, and the flow separation limits the power generation capacity. In order to improve the output power of wind turbines, based on the principle of bionics, the leading-edge protuberance of the humpback whale flipper is introduced to the blade[1]. The research focused on the megawatt-scale wind turbine developed by the National Renewable Energy Laboratory. To study the effect of leading-edge protuberances on the blades, the elevation and taper angle of the wind turbine and the tower are neglected in the study, and the nacelle structure is simplified. Based on the biomimetic principles, the wind turbine blade was modified according to the type of airfoils. Bionic blades can output higher torque and power[2]. The leading-edge protuberances were added at different distances from the wind turbine center. The bionic blades designed in this study had the following parameters, A = 0.4, E = 2.4, N = 6 in region I, and A = 0.2, E = 2.8, N = 13 in region II.

The Cp curves indicated that there exists a significant pressure difference between the suction and pressure surfaces of the airfoil, and the value of the pressure difference in-creases further with the increase of the wind speed. For the bionic blade, the protuberances lead to a significant difference in the shapes of Cp curves for different sections. The performance of the wind turbine can be improved by selecting appropriate parameters. This study provides new research data for the construction of leading-edge protuberances and flow control mechanism, offering valuable guidance for practical applications.

METHOD

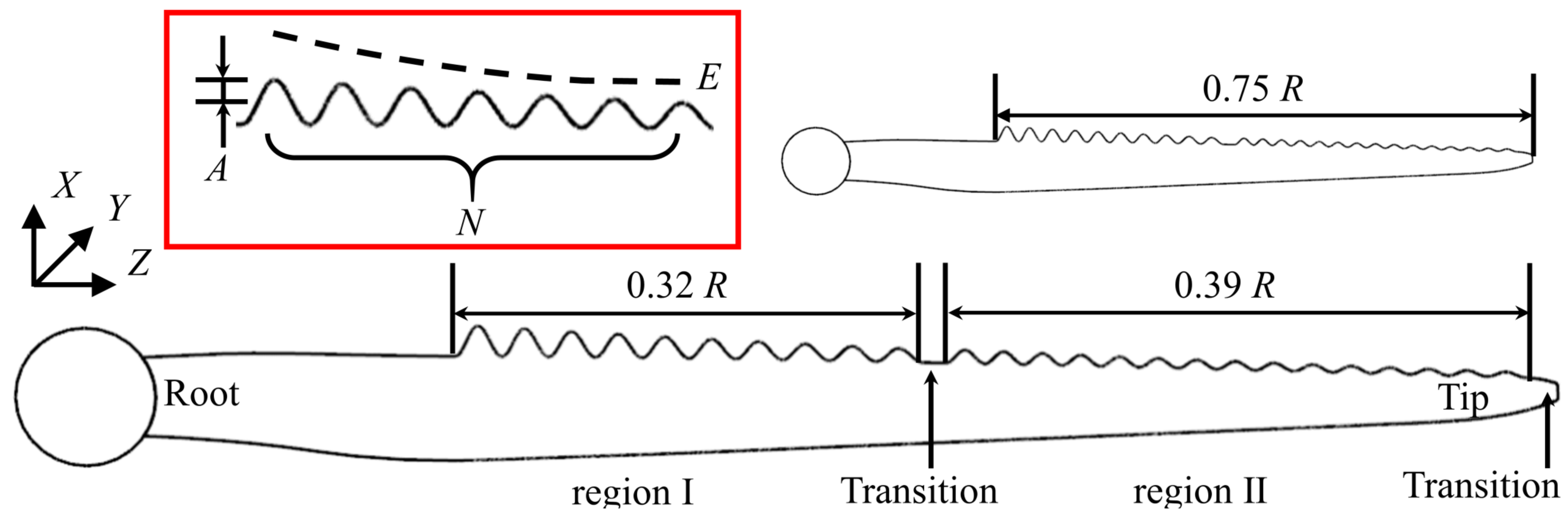

Figure 1. The blade model and bionic protuberance schematic diagram

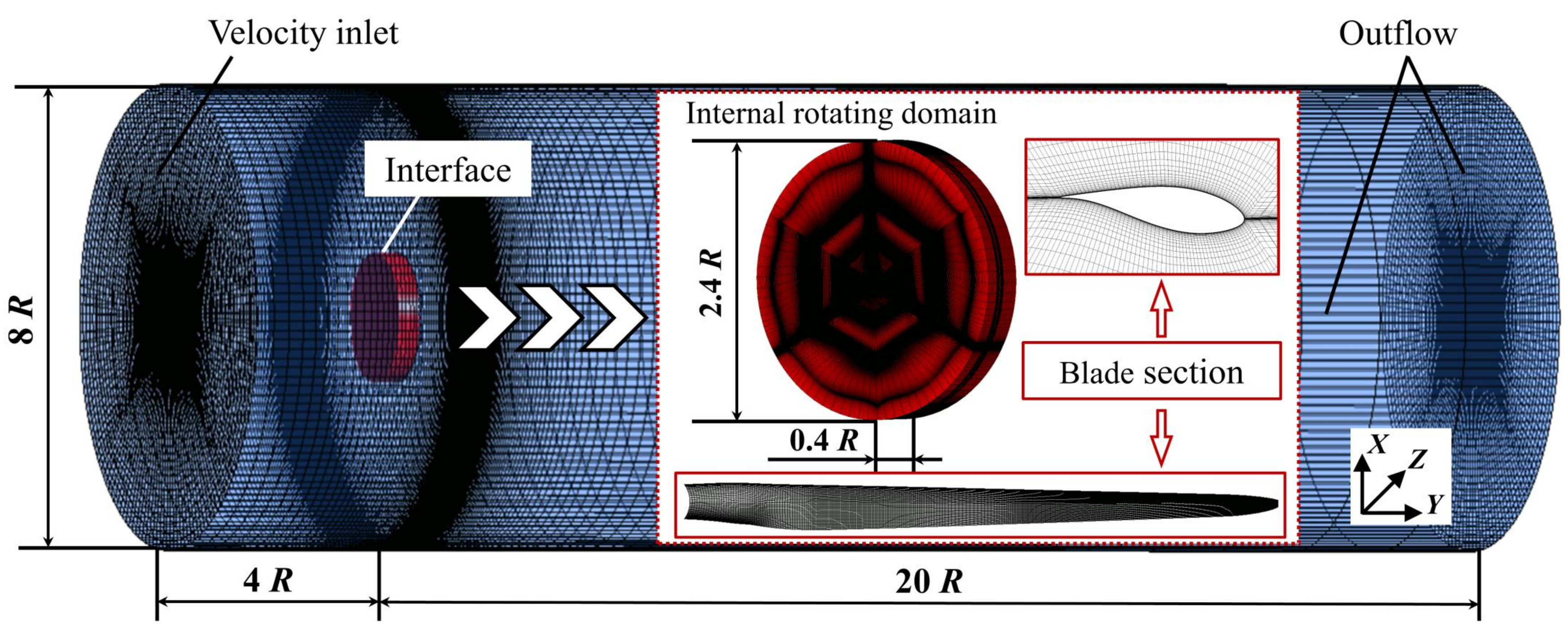

Figure 2. Computational domain model and grid

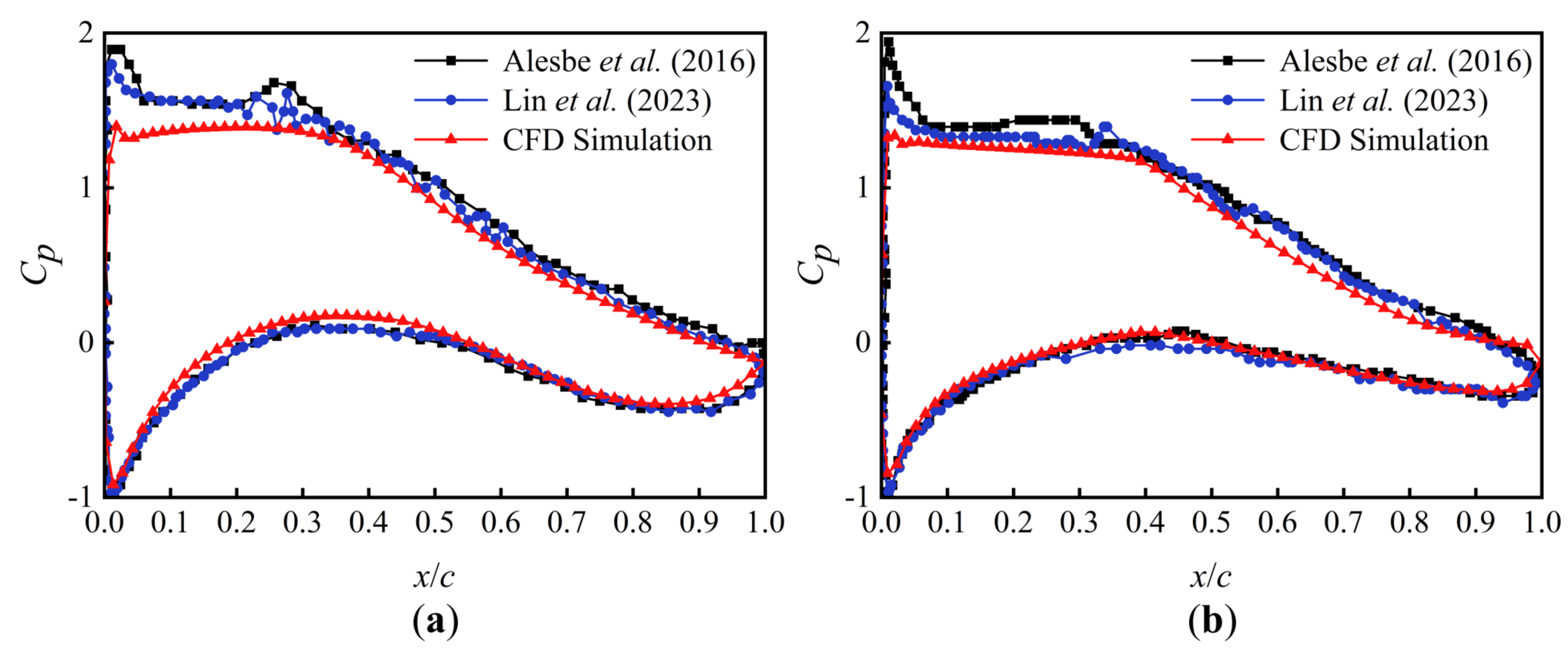

Figure 3. Comparison of the pressure coefficient: (**a**) r/R = 0.6 (**b**) r/R = 0.8.

RESULTS & DISCUSSION

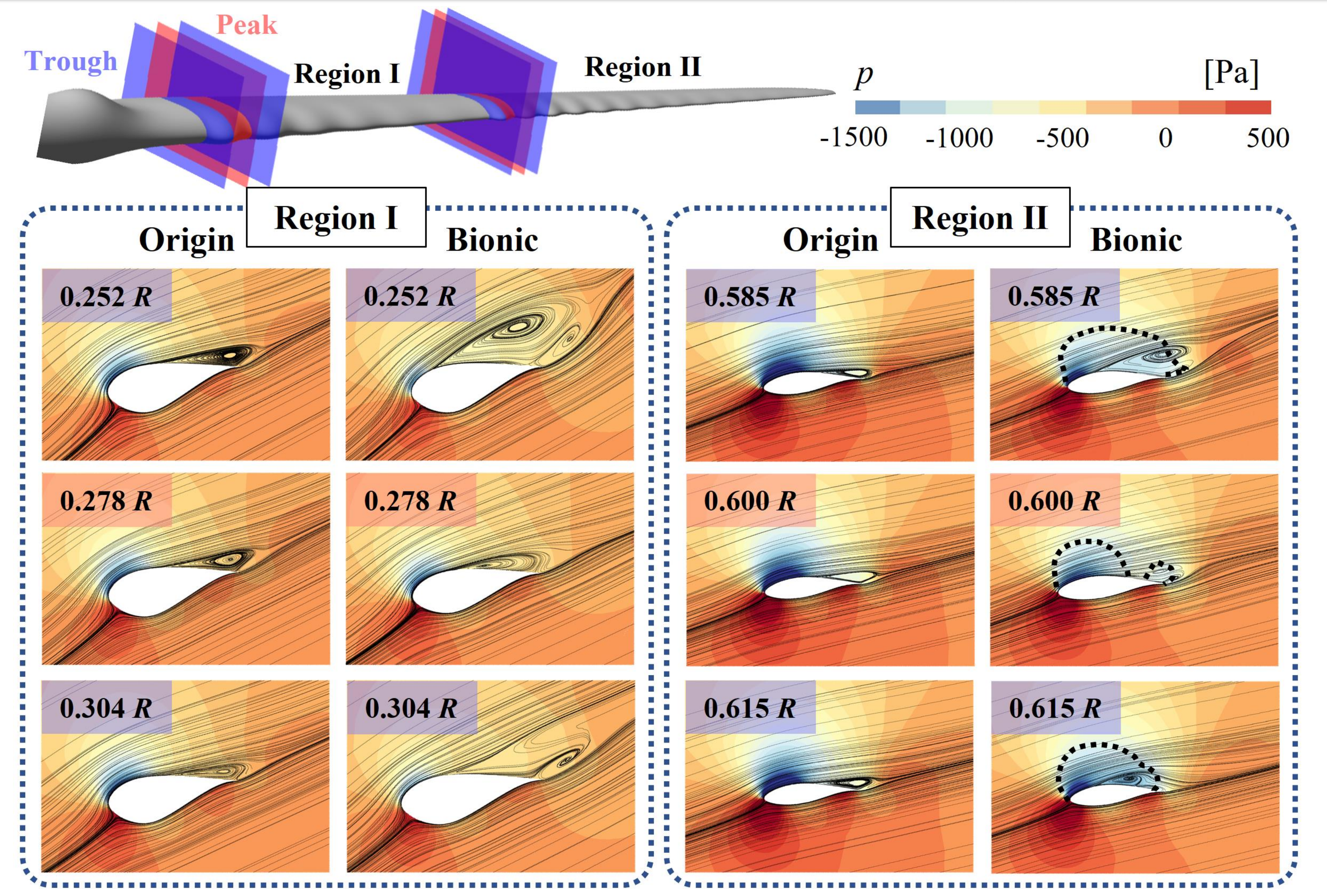

Figure 4. Pressure nephogram and streamline diagram of different blade sections

The streamline variation of the bionic blade was relatively significant. The flow converges towards the trough sections on both sides, leading to intense momentum exchange on the blade surface. The protuberances effectively divided the flow field along the spanwise direction.

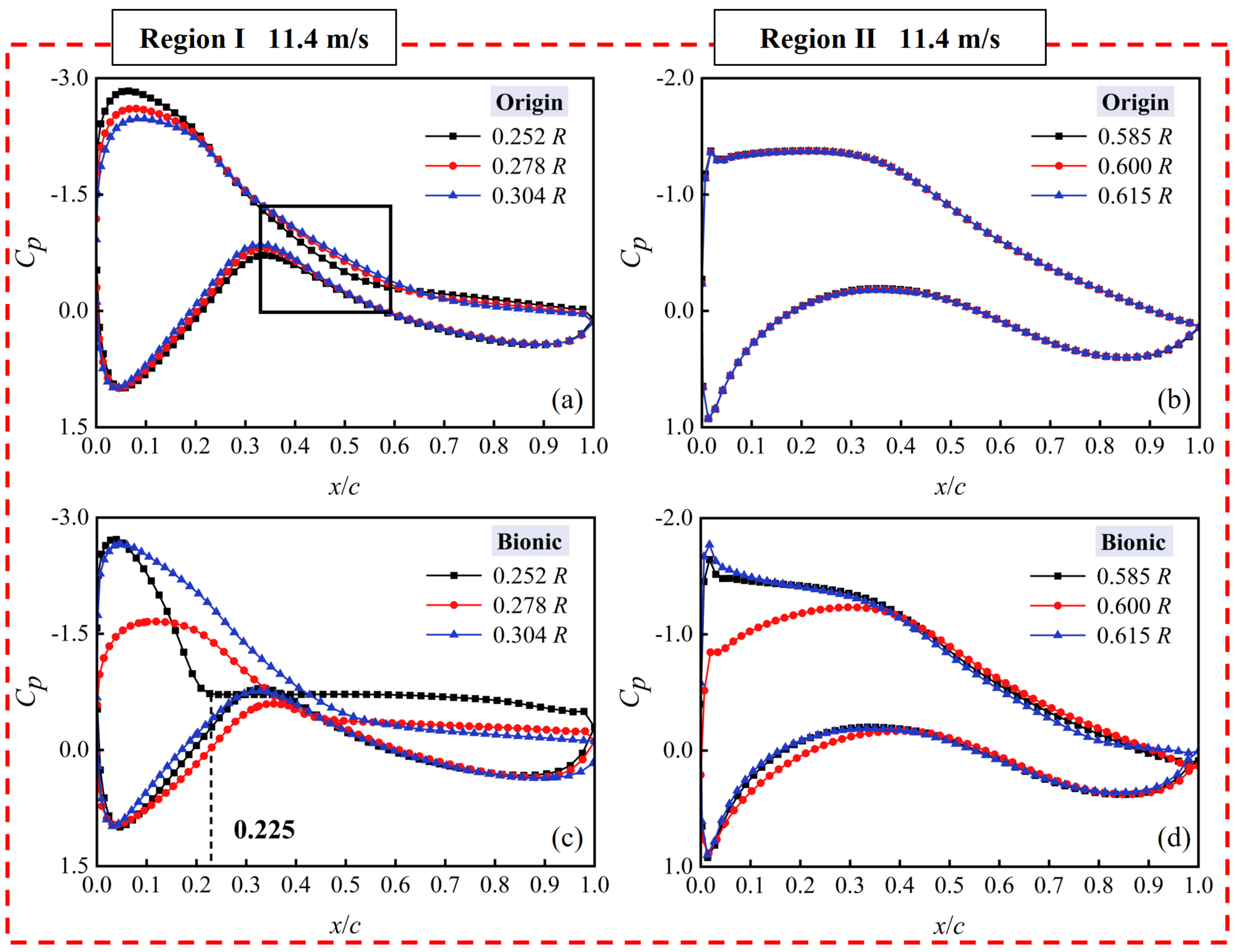

Figure 5. The pressure coefficients of different sections for region I: (a) Original blade (b) Bionic blade; For region II: (c) Original blade (d) Original blade.

CONCLUSION

- The results demonstrate that the protuberances can enhance the performance, delay the flow separation, and increase the area of low pressure region.
- The flow on trough sections was compressed by the flow of peak sections, thereby gaining energy to resist the adverse pressure gradient of the flow.

FUTURE WORK / REFERENCES

- The influence of protuberance parameter combination will be further explored.

[1] Fish, F. E., Howle, L. E., and Murray, M. M., Hydrodynamic flow control in marine mammals, Integrative and Comparative Biology 2008, 6, 788-800.

[2] Ke, W. L., Hashem, I., Zhang, W. W., and Zhu, B. S., Influence of leading-edge tubercles on the aerodynamic performance of a horizontal-axis wind turbine: a numerical study, Energy 2022, 122186.