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Research on the Shape of Biomimetic Airfoil Leading Edge Protuberance

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INTRODUCTION & AIM

In the context of wind power generation, the airfoil is a critical component of wind turbines, significantly impacting turbine performance and blade structural stability. Nearly all airfoils encounter a crucial issue known as stall. Stall occurrence reduces turbine performance and efficiency, affecting the safe and stable operation of the turbine. Hence, investigating stall phenomena and identifying stall control methods is paramount.

The passive control method of adding protuberances to the leading edge of the airfoil is inspired by the tubercles of humpback whale fins. Current research predominantly focuses on sinusoidal protuberance structures, revealing the mechanisms by which these protrusions suppress stall. However, there is limited research exploring the effects and mechanisms of other protuberance shapes on stall suppression.

Therefore, this study selects 8 different protuberance structures for exploration and compares their influences on the aerodynamic performance and underlying mechanisms of airfoil shapes.

METHOD

I. Leading edge protuberances design

8 different shaped protuberance on the leading edge of the base airfoil, and each protuberance shape is named Co_ 1- Co_ 8.

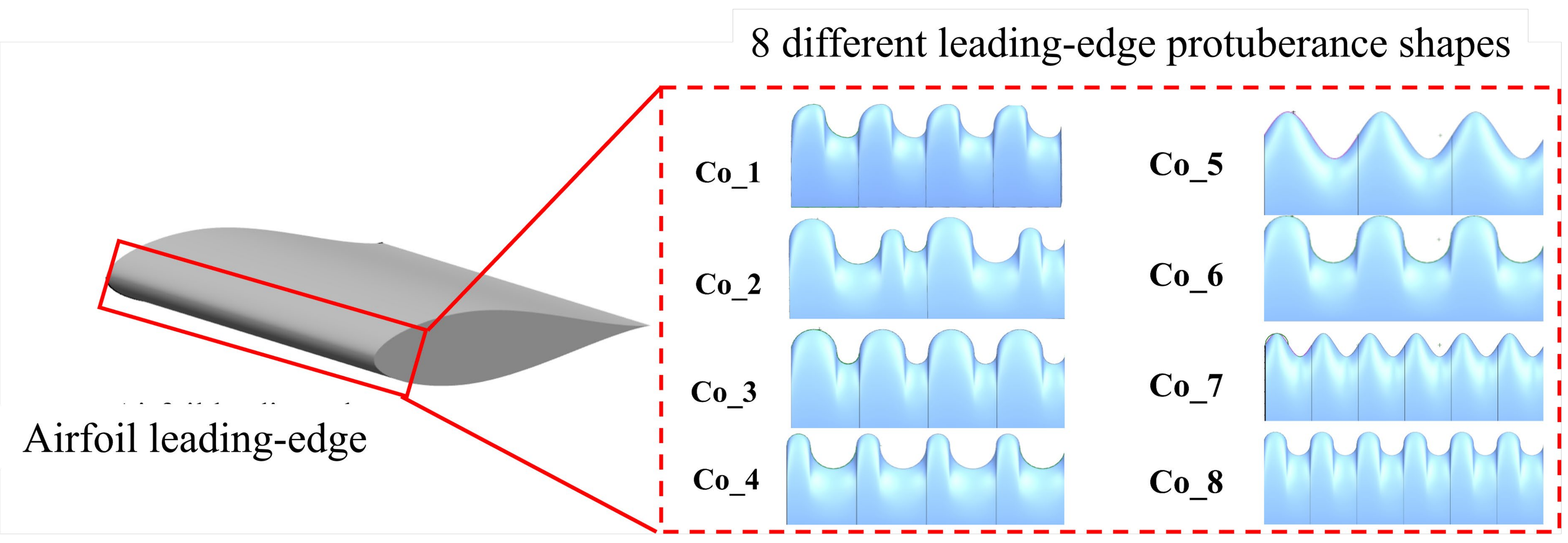

Figure 1. Design of leading-edge protuberance structure

II. Numerical Simulation Method

- NACA 0021
- $U = 13.1$m/s
- $c = 0.2$ m
- SST k- ω

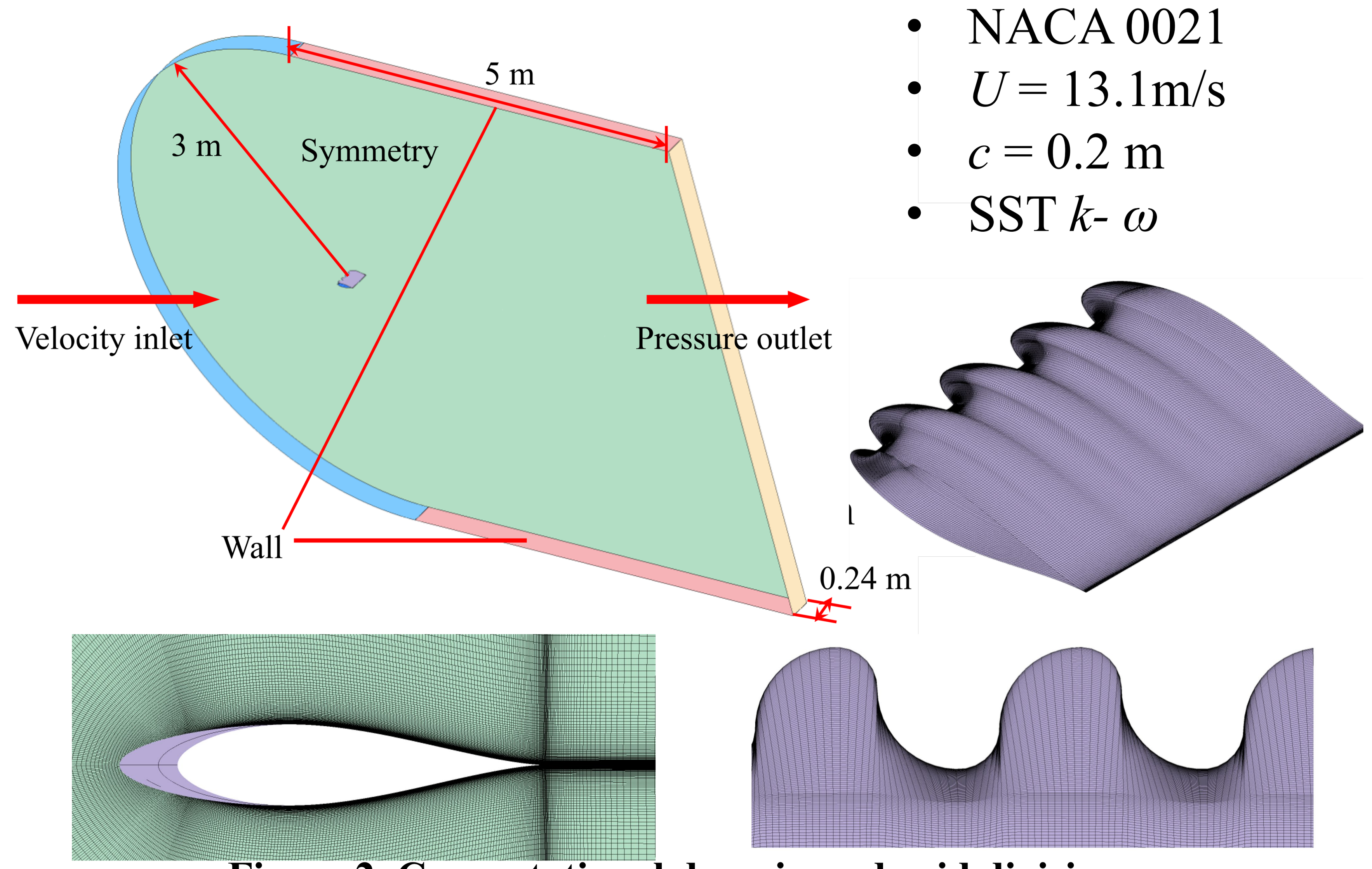

Figure 2. Computational domain and grid division

RESULTS & DISCUSSION

I. External characteristic analysis

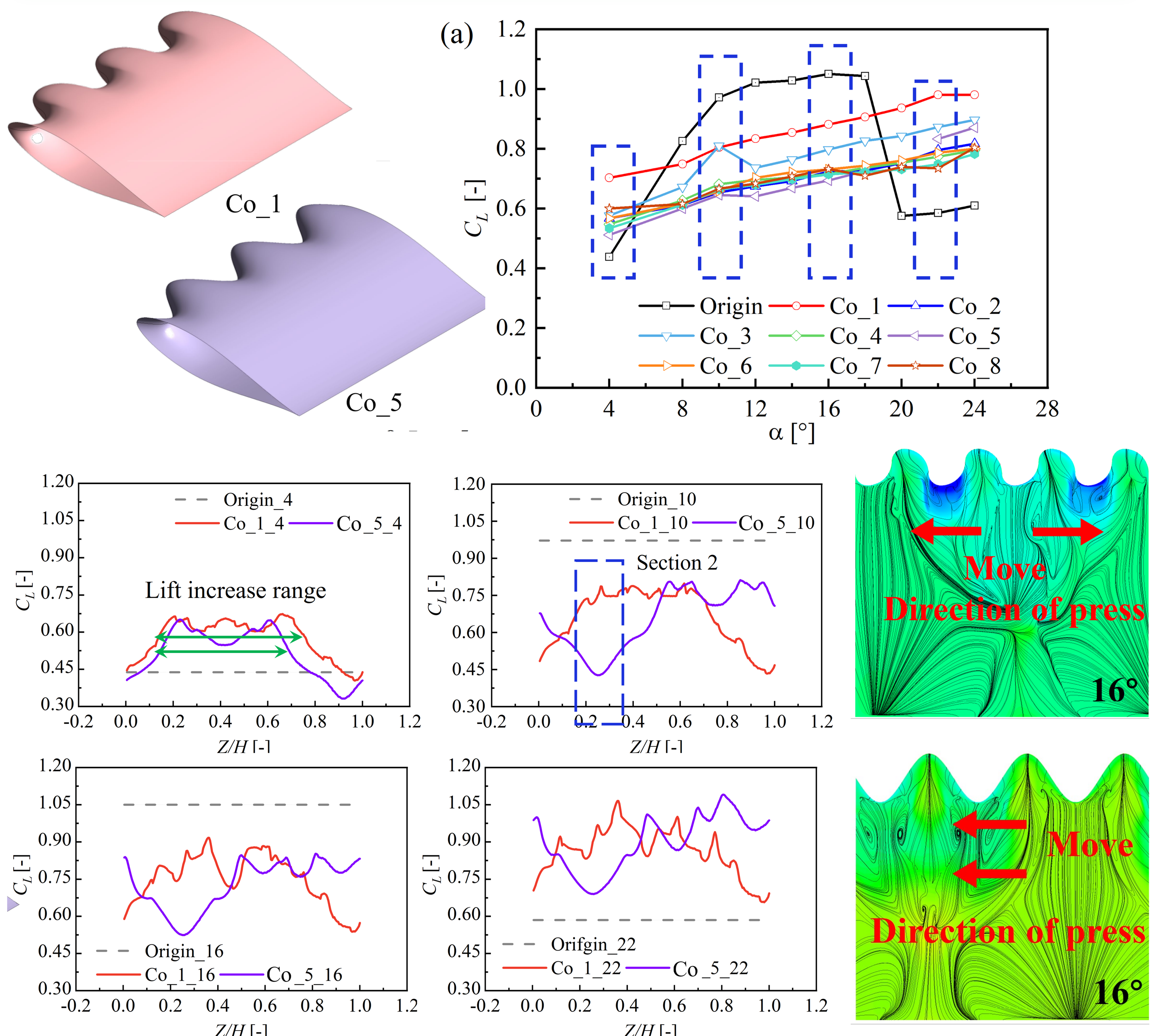

Figure 3. External characteristics and mechanism of action

II. Internal flow characteristic ANALYSIS

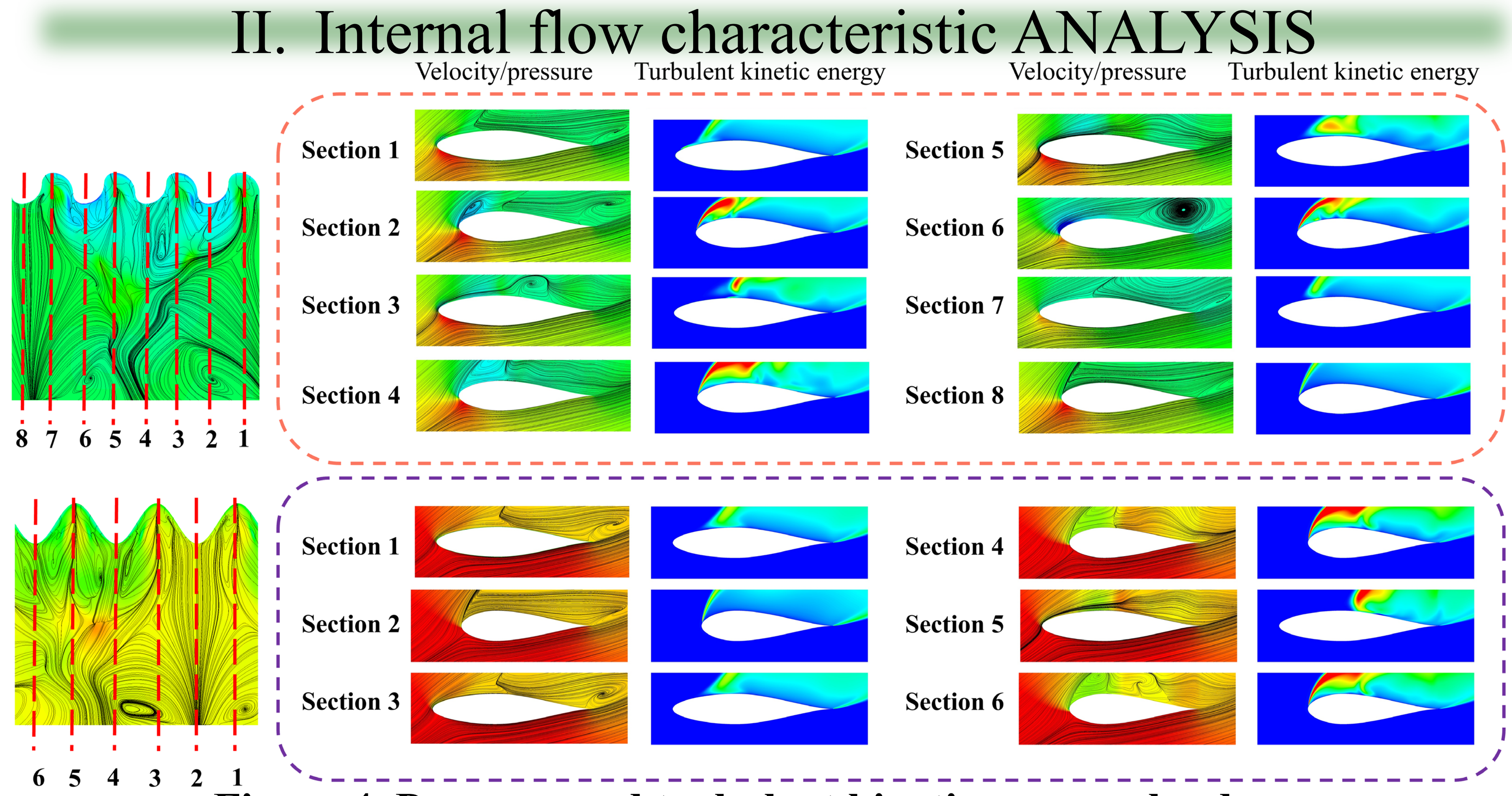

Figure 4. Pressure and turbulent kinetic energy cloud map

CONCLUSION

Co_1 and Co_5 demonstrating superior stall suppression effects. Both protrusion structures enhance flow energy and suppress flow separation along the spanwise direction by moving low-pressure regions. Higher turbulent kinetic energy is observed in both the separation and low-pressure regions.

FUTURE WORK / REFERENCES

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