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Aerodynamic Performance of Aerofoil Droop Leading Edge at Low Reynolds Numbers

Shanshan Xiao, Mark Jabbal, Humberto Medina, Mohammadreza Amoozgar

Fluids and Thermal Engineering Research Group, University of Nottingham

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- Future Work

Introduction

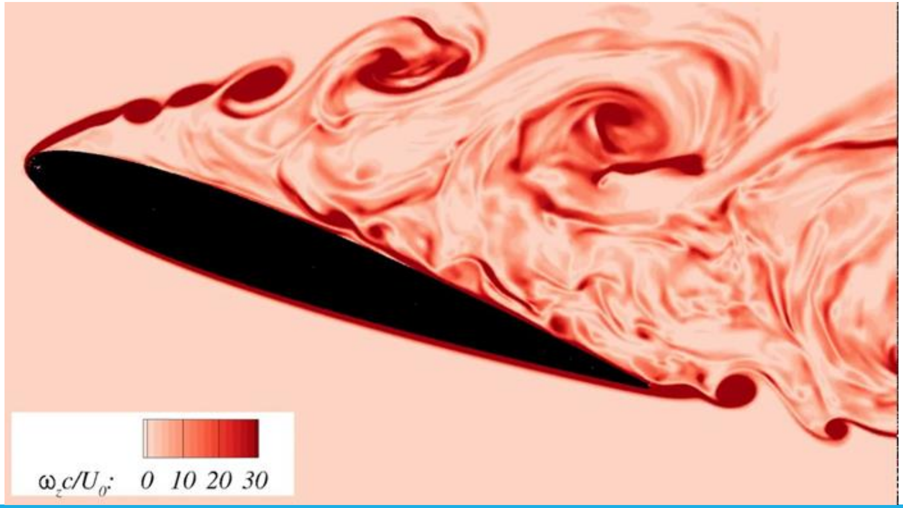
Droop Leading Edge (DLE):

- An aerofoil design changes the effective geometry of the propeller blade
- Delay aircraft stall, enhance lift, reduce drag, and improve rotor efficiency
- Applicable to both helicopter and wind turbine blades

[1] Kota S, Ervin G, Osborn R, et al. Design and fabrication of an adaptive leading edge rotor blade[C]//Annual Forum Proceedings-American Helicopter Society. AMERICAN HELICOPTER SOCIETY, INC, 2008, 64(3): 2178.
[2] Ma Y, Zhao Q, Zhao G. New combinational active control strategy for improving aerodynamic characteristics of airfoil and rotor[J]. Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering, 2020, 234(4): 977-996.

Stall:

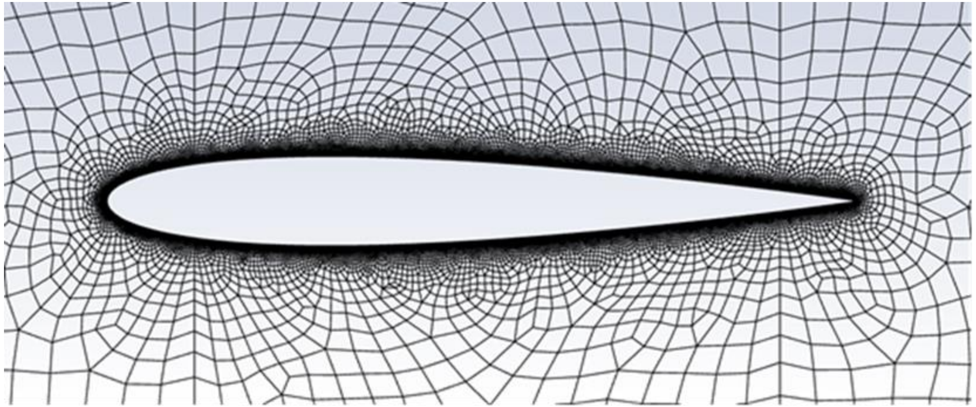
- Common in rotary-wing aircraft and wind turbine blades
- Results in severe aerodynamic loads, vibration, and potential structural damage, impacting both rotorcraft and wind turbine performance
- Understanding and controlling stall is critical for enhancing aerodynamic performance

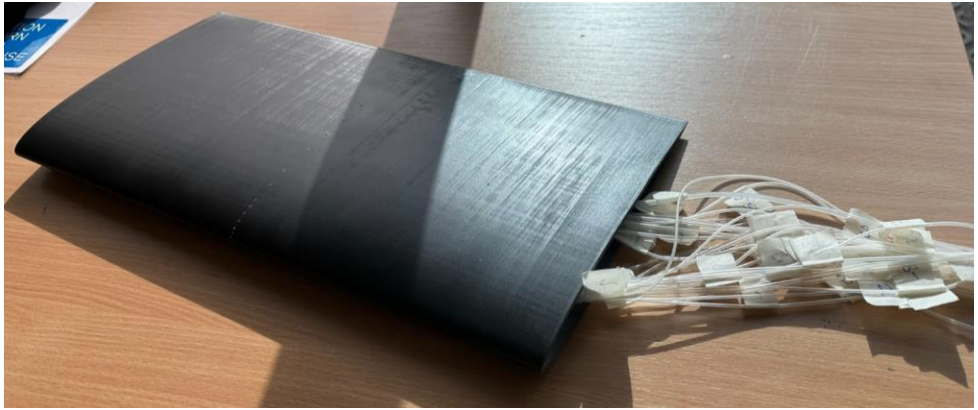


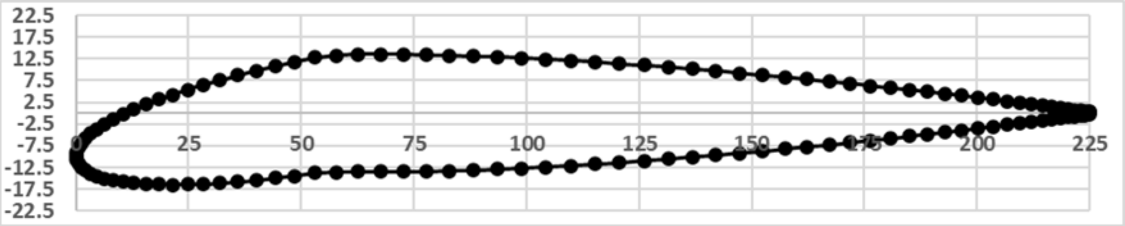
Methodology

Research Methods:

- Computational Fluid Dynamics (CFD) simulations by OpenFOAM
- k-ω Laminar Kinetic Energy (LKE) transition model
- Wind Tunnel Testing (AF1450s, subsonic wind tunnel)
- Three-component force balance and pressure tappings



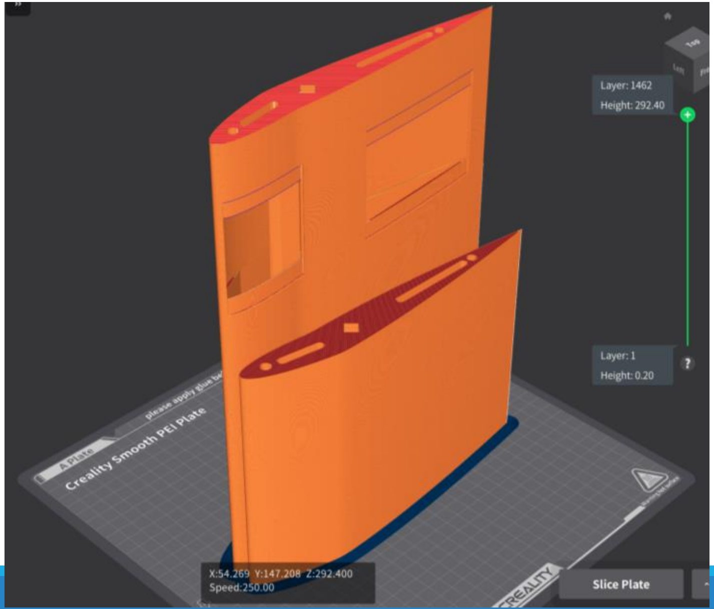


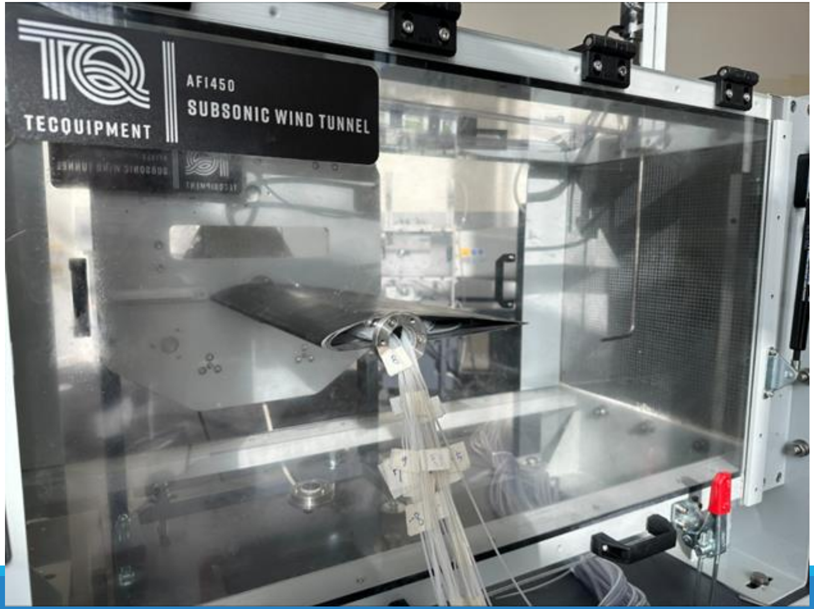


- NACA0012 for baseline
- 3D-printed
- Droop angles (0<δ<30)
- 30 pressure taps over the upper and lower surfaces

DLE Case and Baseline Case Experiments:

- Reynolds number: *100,000 < Re < 300,000 (for MAV and UAV)*
- Droop angle: $\delta = 10°$ *(results till now)*
- Angle of attack: *-20° < α < 20°*

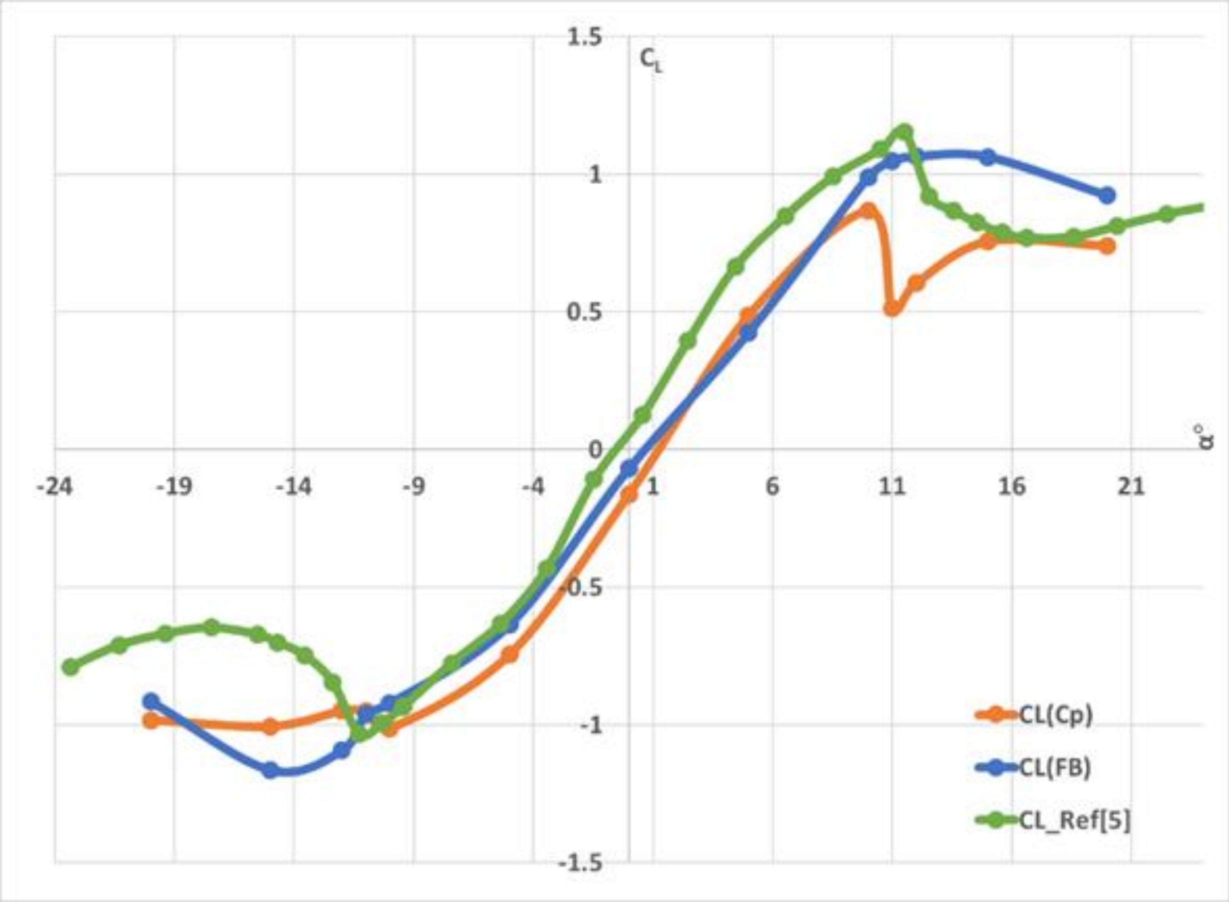




Results and Conclusions

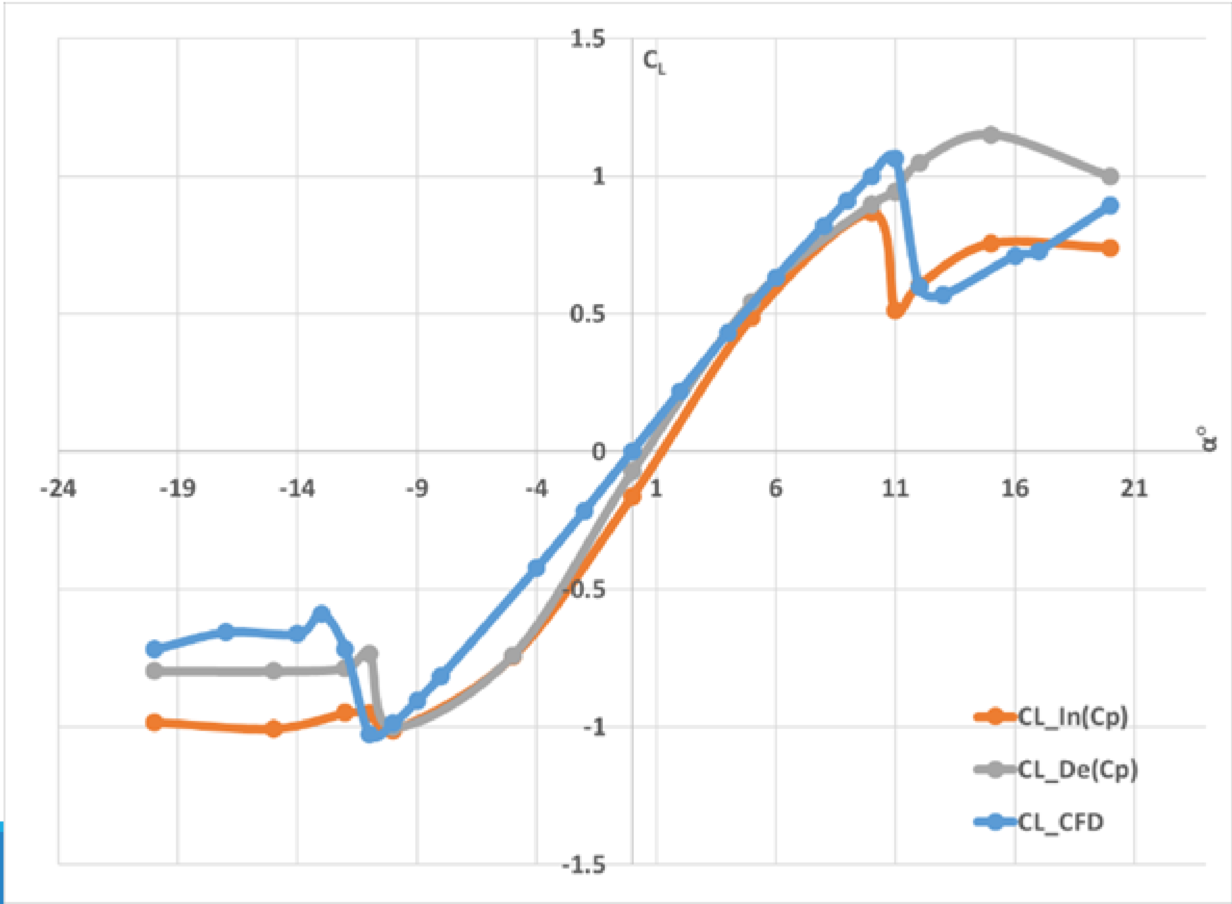
NACA0012 Aerofoil Simulation: ***Re = 200,000***

Measurement method of force coefficient in wind tunnel test



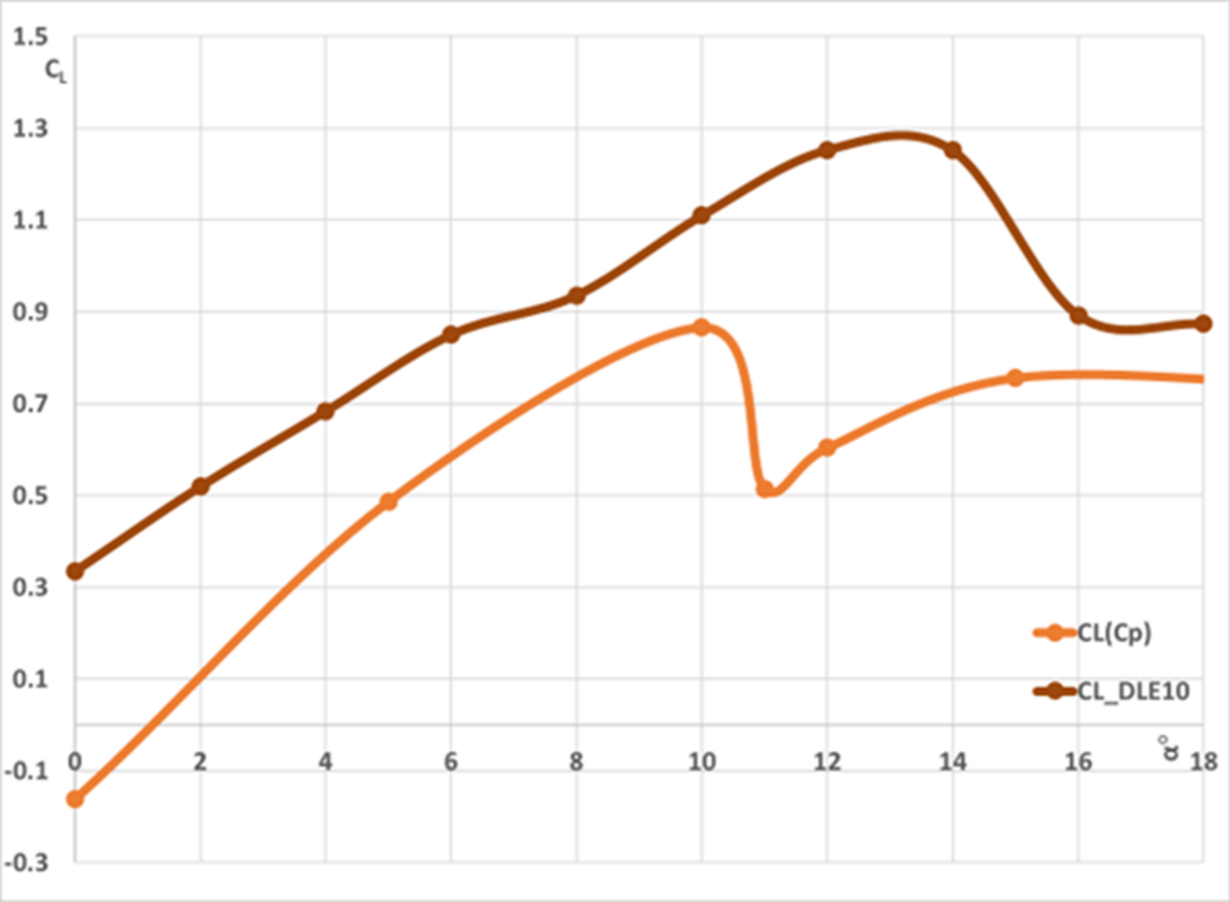
NACA0012 Aerofoil Simulation: *Re = 200,000*

Comparison of wind tunnel test and CFD simulation results



Baseline and 10 deg DLE Aerofoil Simulation: *Re = 200,000*

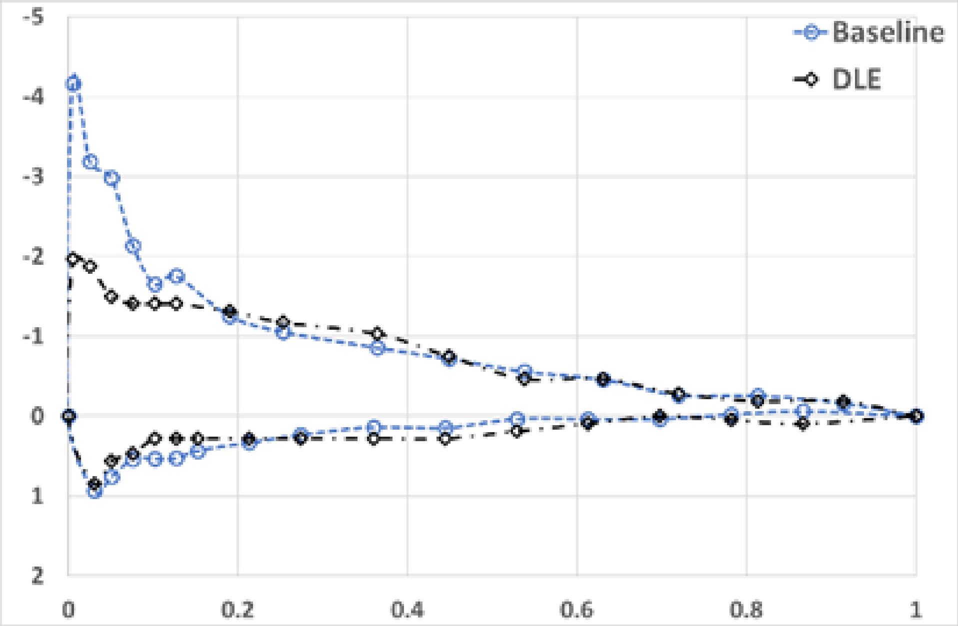
Comparison of Cl and delay dynamic stall



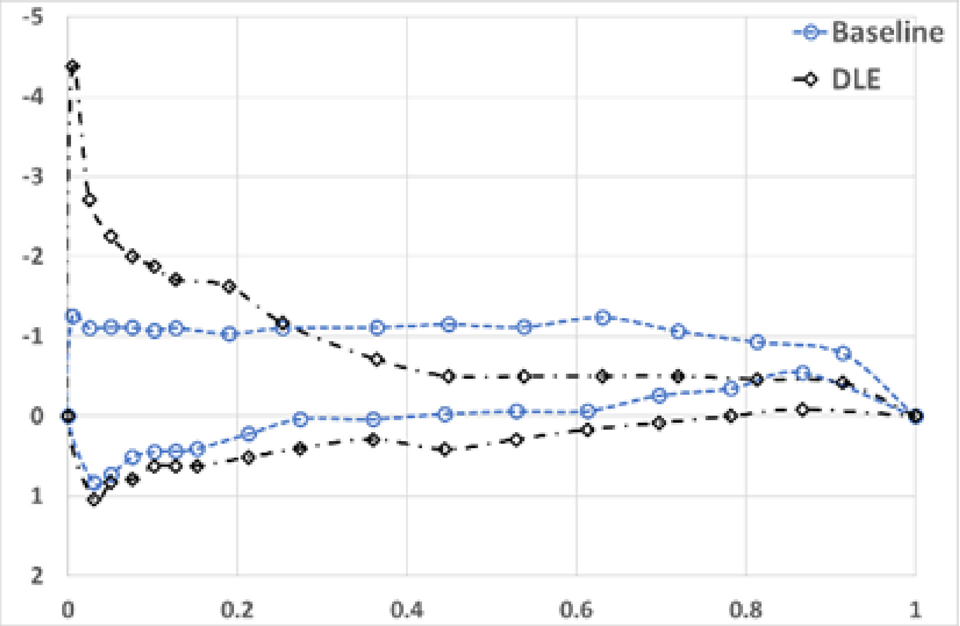
Baseline and 10 deg DLE Aerofoil Simulation: *Re = 200,000*

Pressure Coefficient Distribution:

Cp vs x/c at AoA = 10°



Cp vs x/c at AoA = 16°



Future Work

Conclusion:

- Increase lift
- Delay stall

Next Steps:

- More models, including different droop angles, different droop parts or dynamic models on both experiment and CFD
- Studies on drag coefficient and flow visualization
- Wind tunnel corrections (force balance, blockage)

THANKS

Shanshan Xiao
Shanshan.xiao@nottingham.ac.uk