An Experimental Validation of Numerical Post-Stall Aerodynamic Characteristics of a Wing

Vipul Dalela[a] and Rinku Mukherjee[a1]

[a] Department of Applied Mechanics, Indian Institute of Technology, Madras, Chennai, India

1. INTRODUCTION & OBJECTIVE

The interest in extending linear methods to include post-stall regimes of flow has existed since Prandtl's Lifting Line Theory. A vortex-lattice method algorithm based on a novel decambering approach[1] uses an estimate of the reduction in camber at post-stall angles of attack to account for the change in the coefficients of lift, C_l and pitching moment, C_m from the inviscid case. In a more recent approach, a numerical iterative vortex lattice method is developed[2] to study flow past wing(s) at high angles of attack where the separated flow is modelled using nascent vortex filaments distributed along wing-span. Researchers have also used different ways of estimating the effective angle of attack to account for the loss in lift at high angles of attack.

The primary objective of this paper is to get experimental corroboration of the numerical post-stall predictive algorithms developed. It is also expected to use the 'decambering' technique as a physical tool to control boundary layer behaviour.

In this paper, results are reported from experiments conducted in the Transition and Flow Control Laboratory, Aerospace Engineering Department, IIT Madras as shown in Fig. 1. The subsonic, open circuit wind tunnel has a test section of *0.5m* X *0.5m* X *2m* and a maximum wind-speed of 30m/s. The wing models used have a NACA4415 airfoil section and a chord length, *c=6.3cm* and a span, *b=48cm*. Due to the small size of the wing models, separate models are used for measuring pressures and loads.

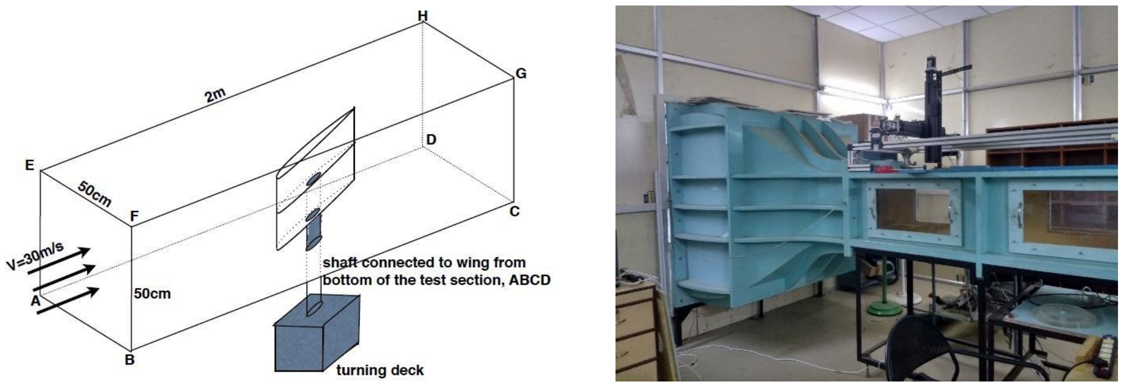
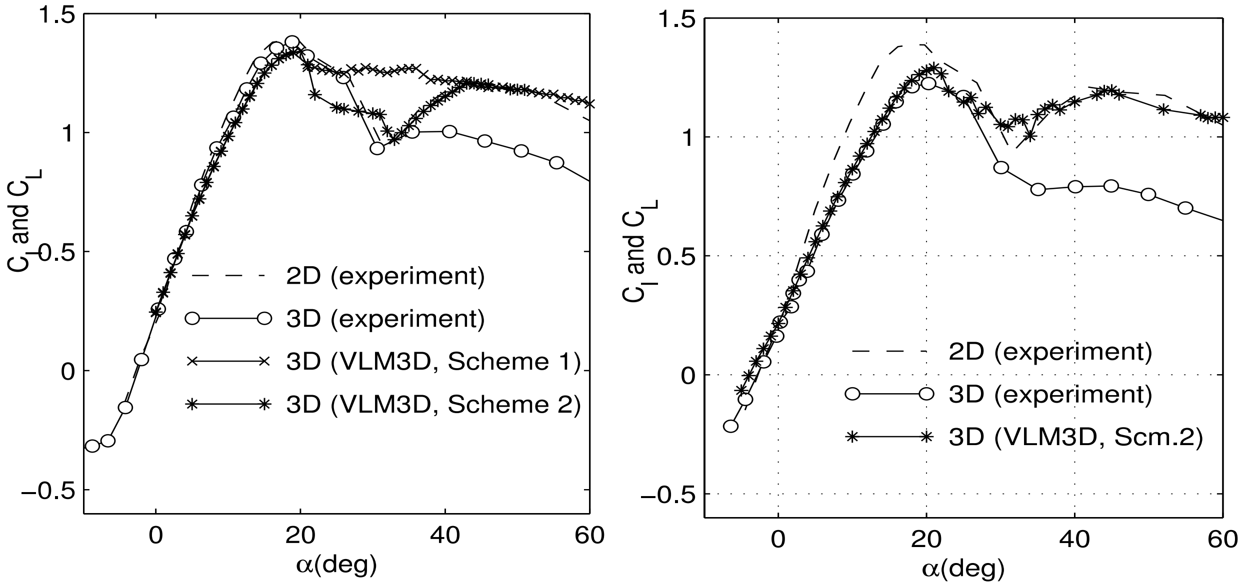


Fig 1: Schematic diagram of Test Section and Wind Tunnel Setup at IIT Madras

[1] Further author information: (Send correspondence to VD)
VD, MS Scholar, E-mail: vdalela15@gmail.com, Telephone: 9424952307, Address: Department of Applied Mechanics, IIT Madras, Chennai, India, 600036
RM, Assistant Professor, E-mail: rinku@iitm.ac.in , Telephone: +44 (0)2257 4069,

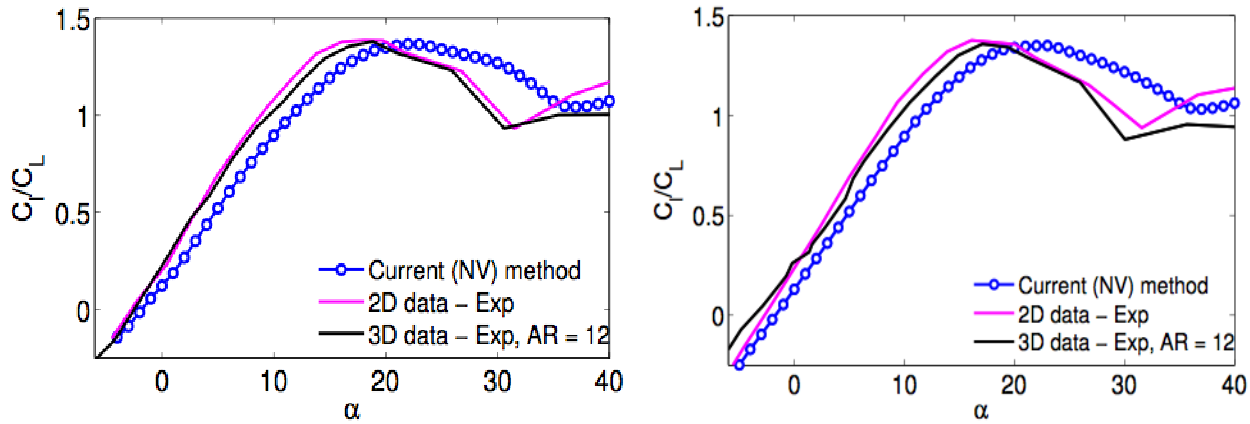
2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

The numerical results that we hope to validate using experiments are presented in Figures 2 and 3 respectively.



(a) Re = 0.5×10^6 (b) Re = 0.75×10^6

Fig 2: 'Decambeing' Technique to model post-stall flow (section: NACA 4415, AR = 12)



(a) Re = 0.5×10^6 (b) Re = 0.75×10^6

Fig 3: *'Nascent Vortex'* model separated flow at post-stall (section: NACA 4415, AR = 12)

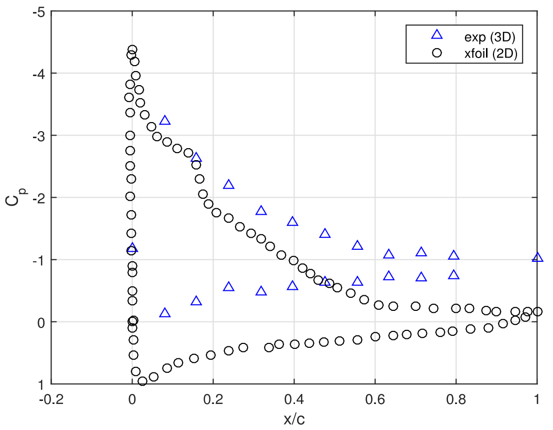
Preliminary experimental results for a 3D wing of aspect ratio, AR=7.6 at $Re = 0.093 \times 10^6$ include coefficients of pressure versus x/c and coefficients of lift and drag versus angle of attack as shown in Fig. 4. The 2D results for an airfoil using XFOIL at $Re = 0.093 \times 10^6$ are also plotted for comparison along with the 3D results.

The present experimental results for C_p shown in Fig. 4(a), calculated about the root section of a 3D wing are compared with XFOIL results for a NACA4415 airfoil. The present experimental results for C_l shown in Fig. 4(b) are compared with experimental 2D results at $Re = 3 \times 10^6$ from Abott[5]. The present experimental results for both C_l and C_d shown in Figures 4(b) and 4(c) respectively are also compared with experimental 3D results for a wing of aspect ratio, AR=6 at $Re = 0.25 \times 10^6$ from Naik and Ostowari[6].

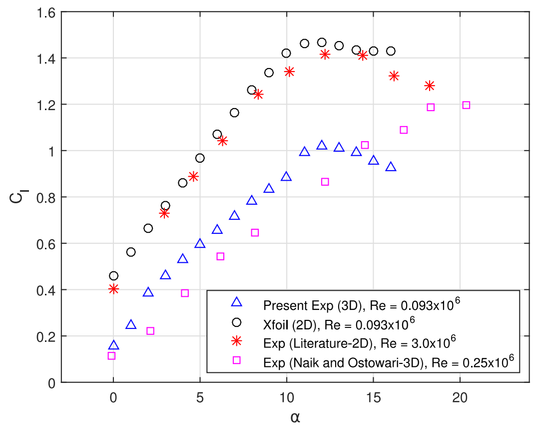
Pressures are calculated using scanivalve and then the output is post-processed to calculate the lift force L by integration of pressure distribution. Hence, the coefficient of lift is then calculated as Eqn. 1.

$$C_l = \frac{L}{\frac{1}{2}\rho A V^2} \tag{1}$$

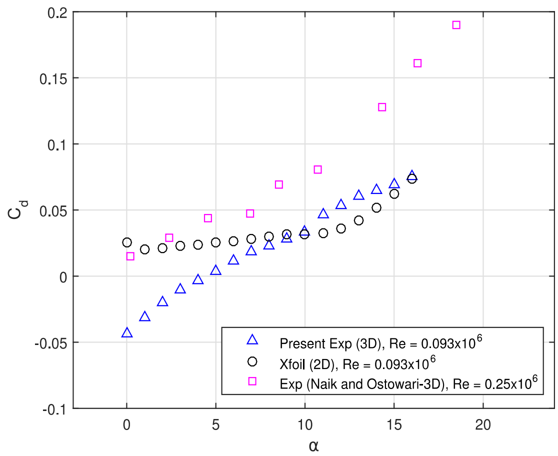
For the coefficient of pressure plot, in the current experiment, pressure ports are mounted in the root section and the ports on the bottom of the model are slightly off compared to that on the top surface.



(a) C_p at α = 15°



(b) C_l



(c) C_d

Fig. 4. Current Experiments

REFERENCES

1. Mukherjee, R., Gopalarathnam, A., and Kim, S., “An Iterative Decambering Approach for Post- Stall Prediction of Wing Characteristics Using Known Section Data”, AIAA 2003-1097.
2. Antony B. Samuel and Rinku Mukherjee, “High-Alfa Aerodynamics with Separated Flow Modeled as a Single Nascent Vortex”, Journal of Physics: Conf. Series, Vol. 822 (2017) 012005, doi:10.1088/1742-6596/822/1/012005
3. J. Marchman III. "Clark-Y airfoil performance at low Reynolds numbers", 22nd Aerospace Sciences Meeting, Aerospace Sciences Meetings, Reno,NV
4. Yeon Sik Baik, Jonathan M. Rausch, Luis P. Bernal, “Experimental study of pitching and plunging airfoils at low Reynolds numbers”, 39th AIAA Fluid Dynamics Conference, AIAA 2009-4030.
5. IRA H.Abbott, Albert E Von Doenhoff, Theory of Wing Sections including a summary of Airfoil Data, Dover Publications Inc. 1959.
6. Ostowari, C. and Naik, D., Post Stall Studies of Untwisted Varying Aspect Ratio Blades with an NACA 4415 Airfoil Section Part 1, Wind Engineering, Vol. 8, No. 3, 1984,pp. 176194.