

# Control of flow structure over a non-slender delta wing using passive bleeding

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## Motivation and Objective:

In recent years, researchers pay a great attention to the studies related with flow control over non-slender delta wings, which can be considered as simplified planforms of Unmanned Air Vehicles (UAV), Unmanned Combat Air Vehicles (UCAV) and Micro Air Vehicles (MAV). The flow control strategies primarily aim to enhance shear layer re-attachment or to delay vortex breakdown and three-dimensional surface separation/stall. Passive bleeding is a passive flow control technique, which utilizes inherent pressure difference between the suction and the pressure side, and thus the flow is transferred through the simple passages over the wing. Celik et al. (2017) aimed to find an effective bleeding orientation on 45 degree swept delta wings, where three different configurations have been tested including Back (B), Edge (E), and Back-Edge (BE). According to their results, with a proper slot orientation, passive bleeding might eliminate the three-dimensional surface separation on 45 degree swept delta wing. In the current study, the effects of bleeding passage orientation defined as back angle ( $\theta$ ) and bleeding passage size defined as bleed opening ratio,  $bor$ , on both the flow structure and aerodynamic coefficients have been studied.

## Methodology:

Experiments were performed in a low speed wind tunnel.

Six different delta wings used during the study. The wings have the same geometrical dimensions that are 135 mm chord, 270 mm span, and 8 mm thickness and are windward beveled with 45 degree angle.

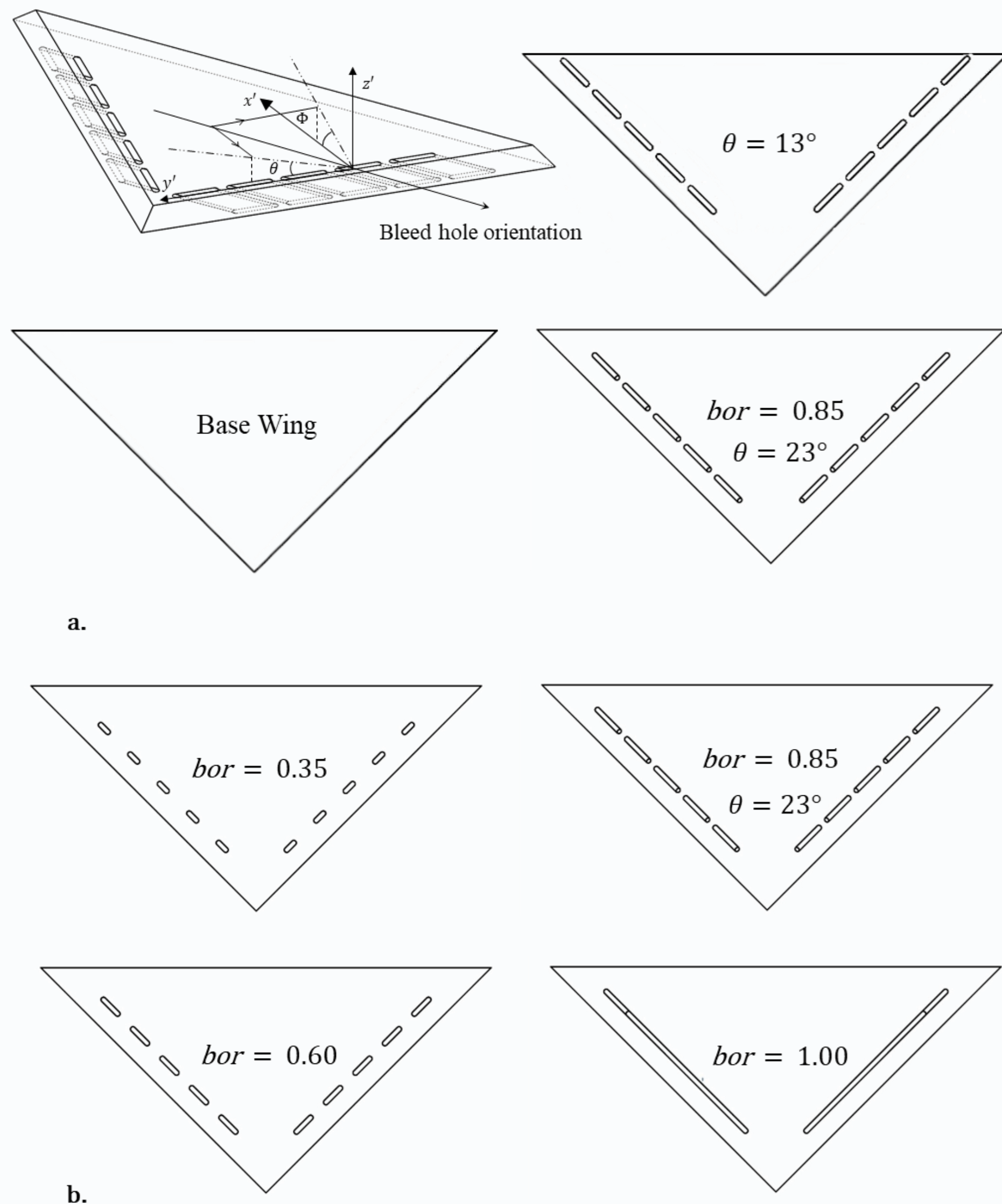


Figure 1. Geometric details of the wings used in experiments.

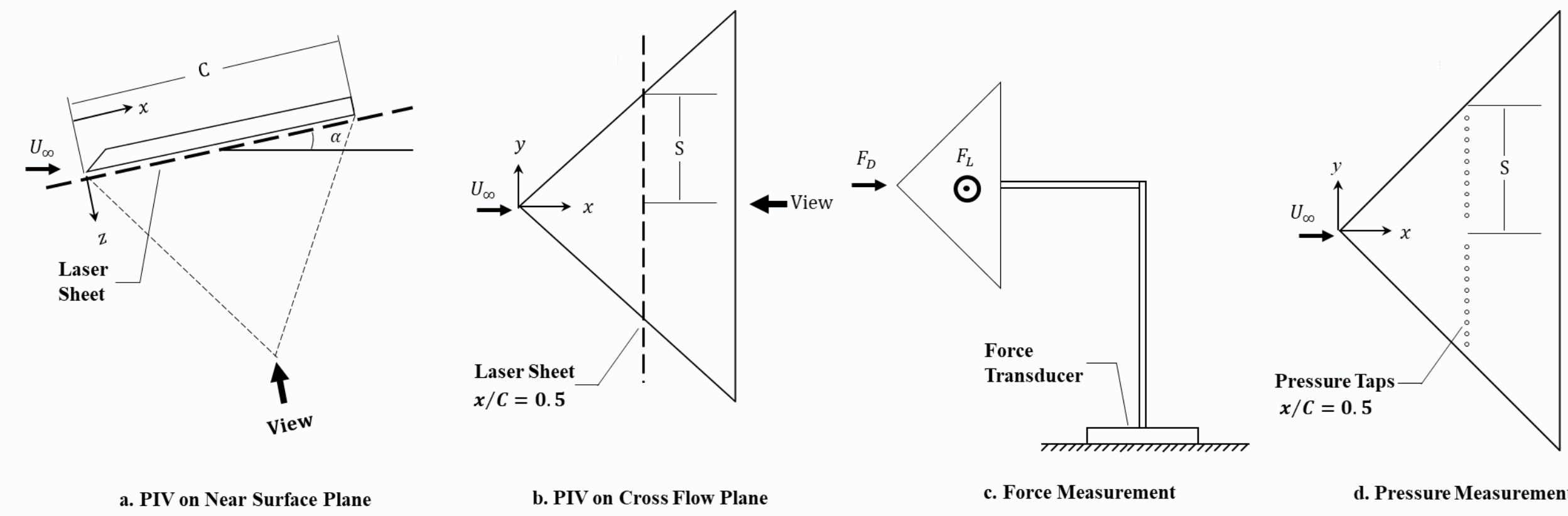


Figure 2. Schematic representations of the measurement systems

As presented in Fig. 1, to investigate the effect of back angle ( $\theta$ ) on flow structure, Base wing and two wings with different back angles  $\theta = 13$  and  $23$  degrees were used. To investigate the effect of bleeding passage size on flow structure, bleed opening ratio,  $bor$ , is defined as the ratio of the total area of the bleed passages of the corresponding wing to that of the wing with maximum bleed opening which is defined as  $bor = 1.00$ . In Fig. 1, wings with different bleed opening ratios,  $bor = 0.35, 0.60, 0.85$  and  $1.00$  are demonstrated. The schematic representations of the measurement systems including PIV on near surface and cross flow planes, surface pressure measurements, and aerodynamic force measurements are depicted in Fig. 2.

## Results:

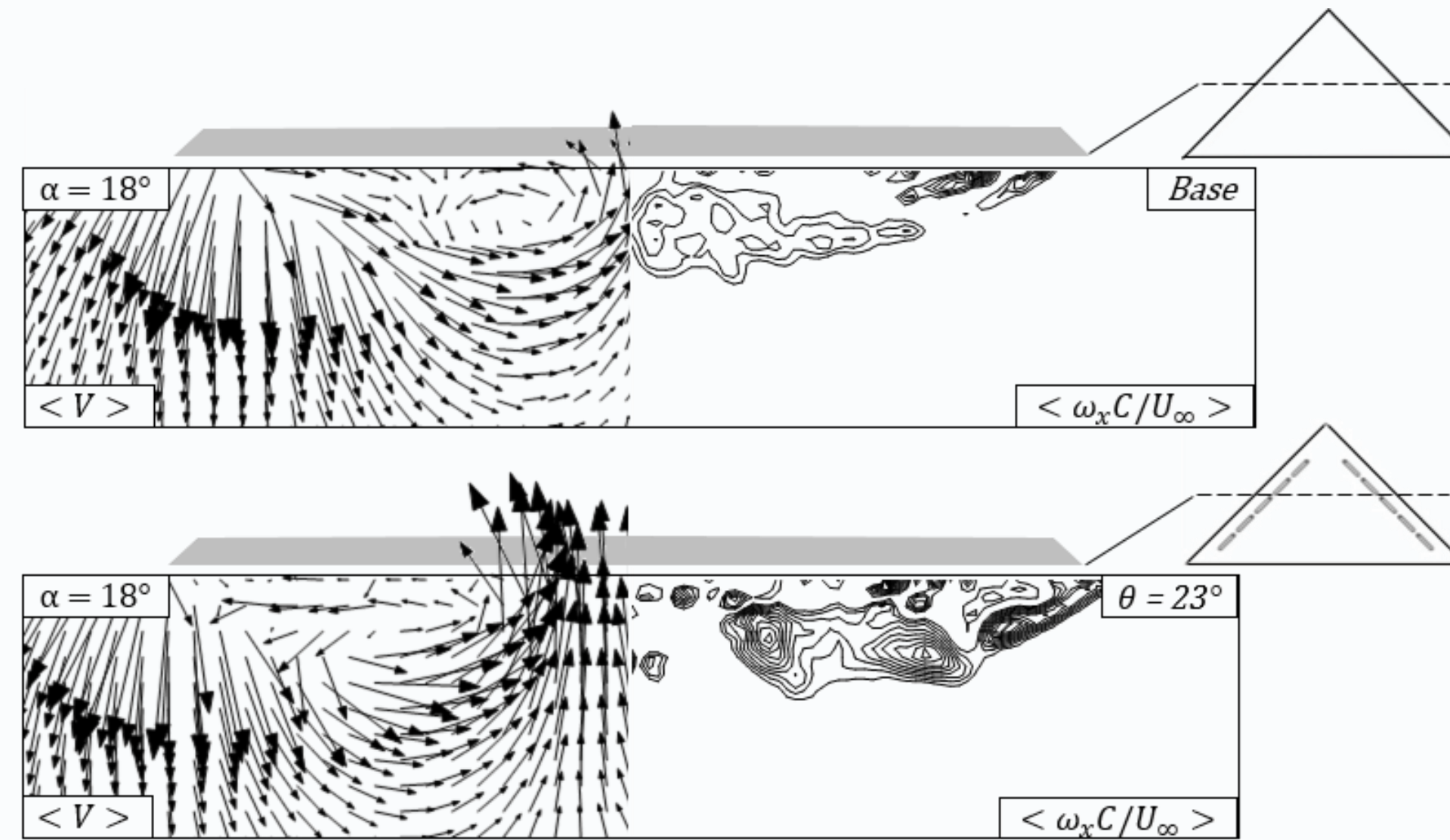


Figure 3. Cross flow PIV results for angle of attack of 18 degree and  $Re = 3.5 \times 10^4$

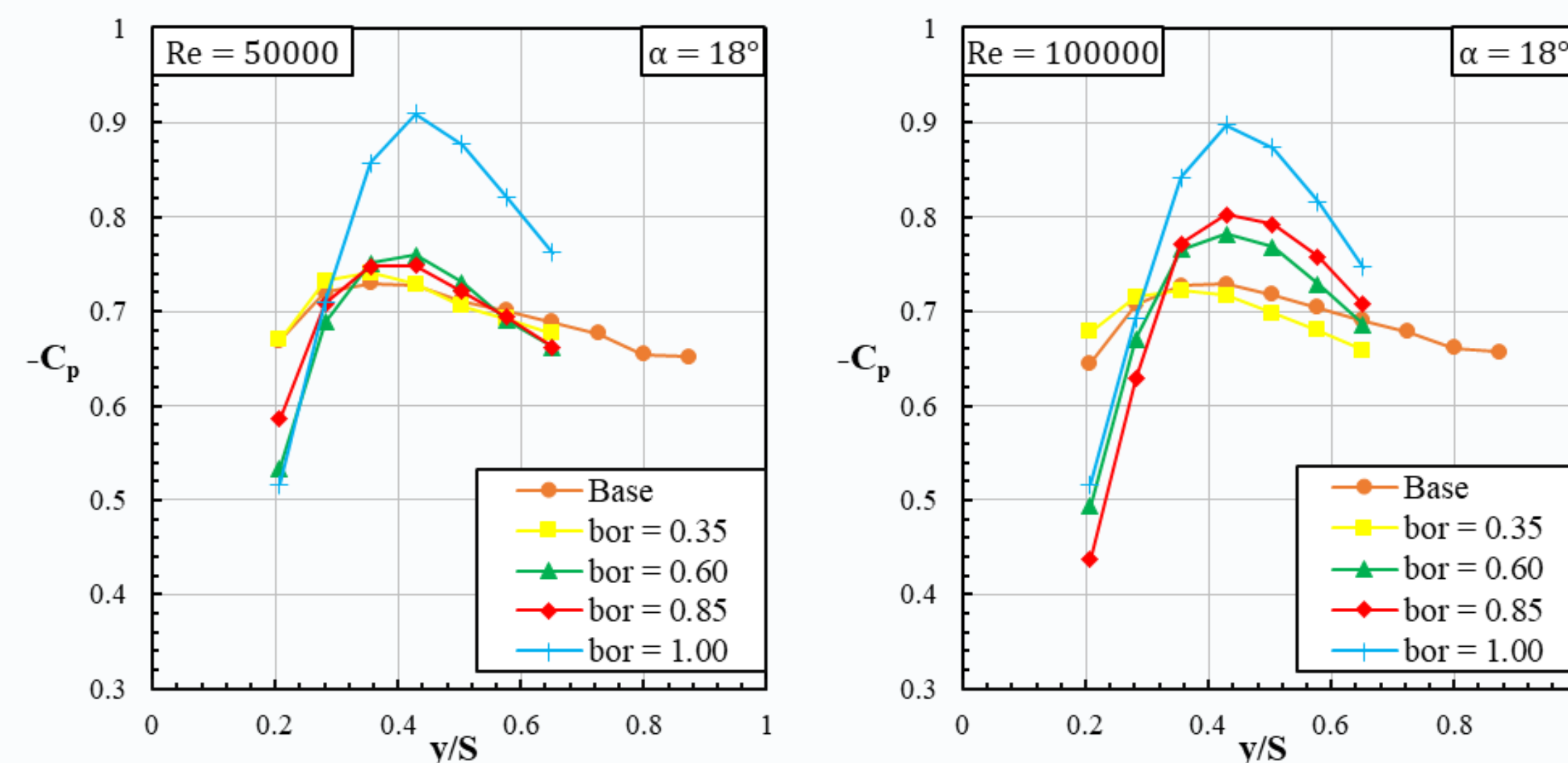


Figure 4.  $-C_p$  distribution along half length of the span at the corresponding chordwise distance for angle of attack of 18 degree and  $Re = 5 \times 10^4$  &  $1 \times 10^5$

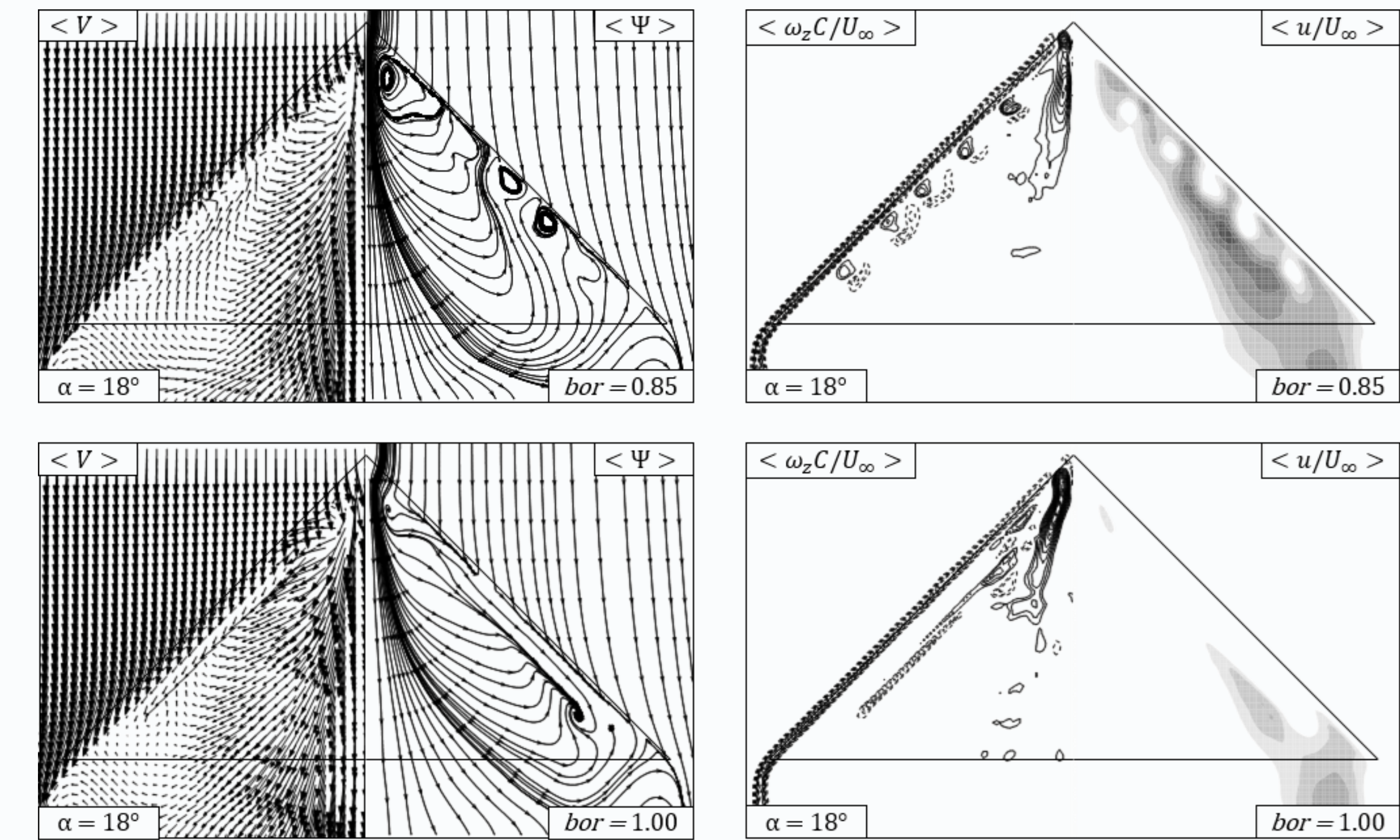


Figure 5. Near surface PIV results for angle of attack of 18 degree and  $Re = 5 \times 10^4$

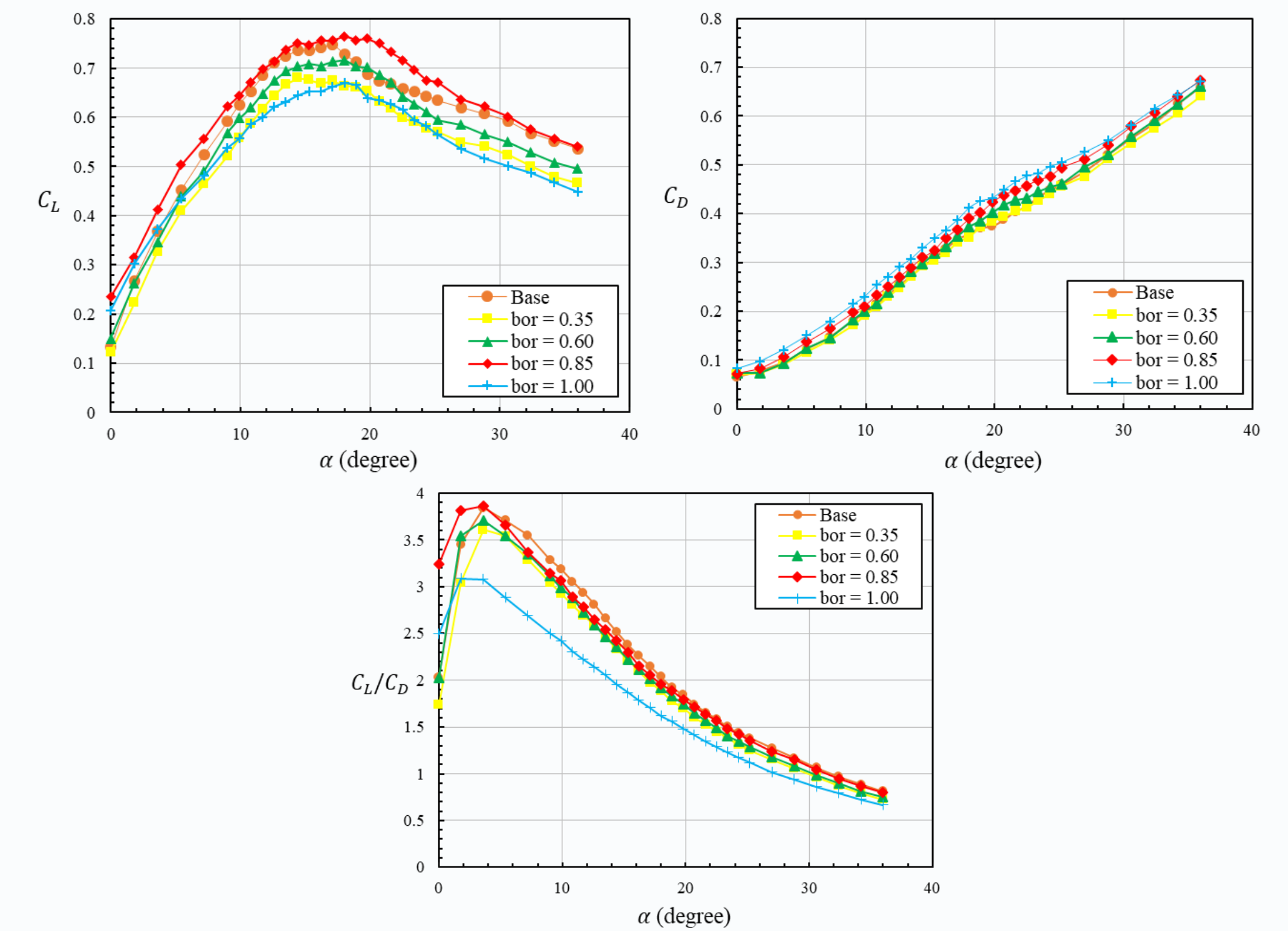


Figure 6. Lift coefficient, Drag coefficient, and Lift-to-Drag ratio with respect to angle of attack at  $Re = 1 \times 10^5$

## Conclusions:

- 1) At sufficiently high angle of attack,  $\alpha = 18^\circ$ , where the pronounced surface separation appears on the Base planform, the elimination of three-dimensional surface separation and recovery of leading-edge vortex are achieved with passive bleeding, which are indicated by significant increases in the magnitudes of surface normal vorticity and suction pressure coefficient  $-C_p$ .
- 2) Increase in both back angle  $\theta$  and bleed opening ratio, provide enhancements in the elimination of three-dimensional surface separation. The wing with  $bor = 1.00$  outperforms the others in the elimination of flow separation.
- 3) Considering the aerodynamic coefficients, the wing with  $bor = 0.85$  augments the lift coefficient at all angles of attack and  $C_L/C_D$  at low angles of attack, and delays the stall significantly compared to the Base wing, hence, appears to induce the best aerodynamic performance among all bleed configurations.