Effect of Thickness-to-Chord Ratio on Aerodynamics of Non-slender Delta Wing

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Motivation and Objective:

In recent decades, the prevailing usage of delta wings in the design of unmanned air vehicles (UAVs), micro air vehicles (MAVs), and fighter jets motivated extensive studies on flow control and characterization of these planforms. The investigations in this area date back to 1960's, however supplementary studies are required to elucidate the flow topology and aerodynamics, reduce the flow instabilities, and enhance the overall performance of delta wings during steady flights and manoeuvres.

For non-slender delta wings, a very few studies have addressed the thickness effect on aerodynamic forces and flow structure. Recently, Gülsaçan et al.* investigated the effect of thickness-to-chord (t/C) ratio on flow structure of a 35 deg swept delta wing, and concluded that the effect of t/C ratio on flow structure of delta wings is as significant as the effect of angle of attack. The aim of the present research is to characterize the t/C ratio effect on both the flow structure and the aerodynamic forces of a 45 deg swept sharp-edged delta wing.

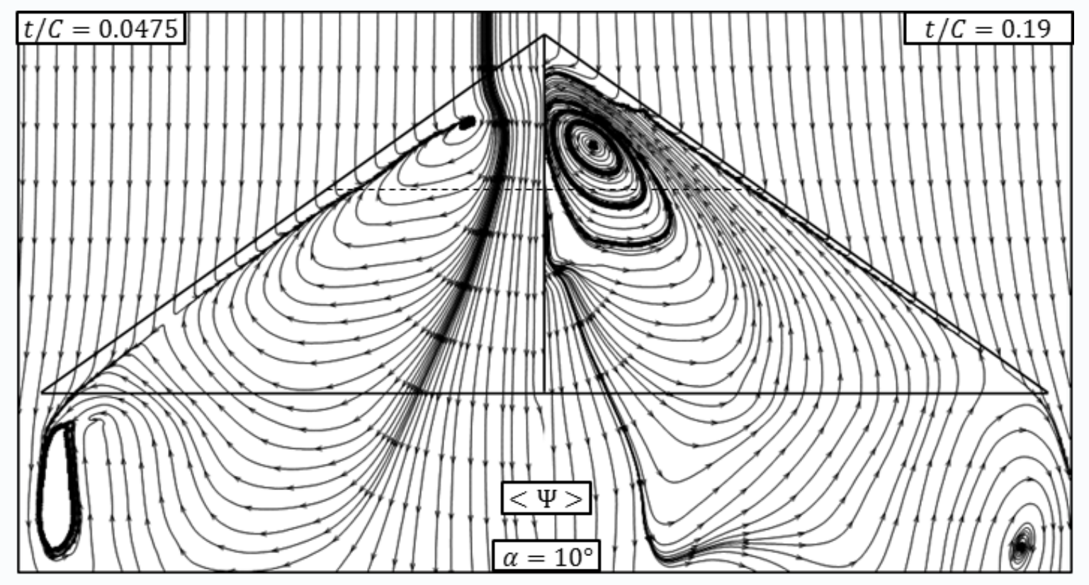

Figure 1. Effect of t/C ratio on time averaged streamlines <Ψ> of a 35 deg swept delta wing.*

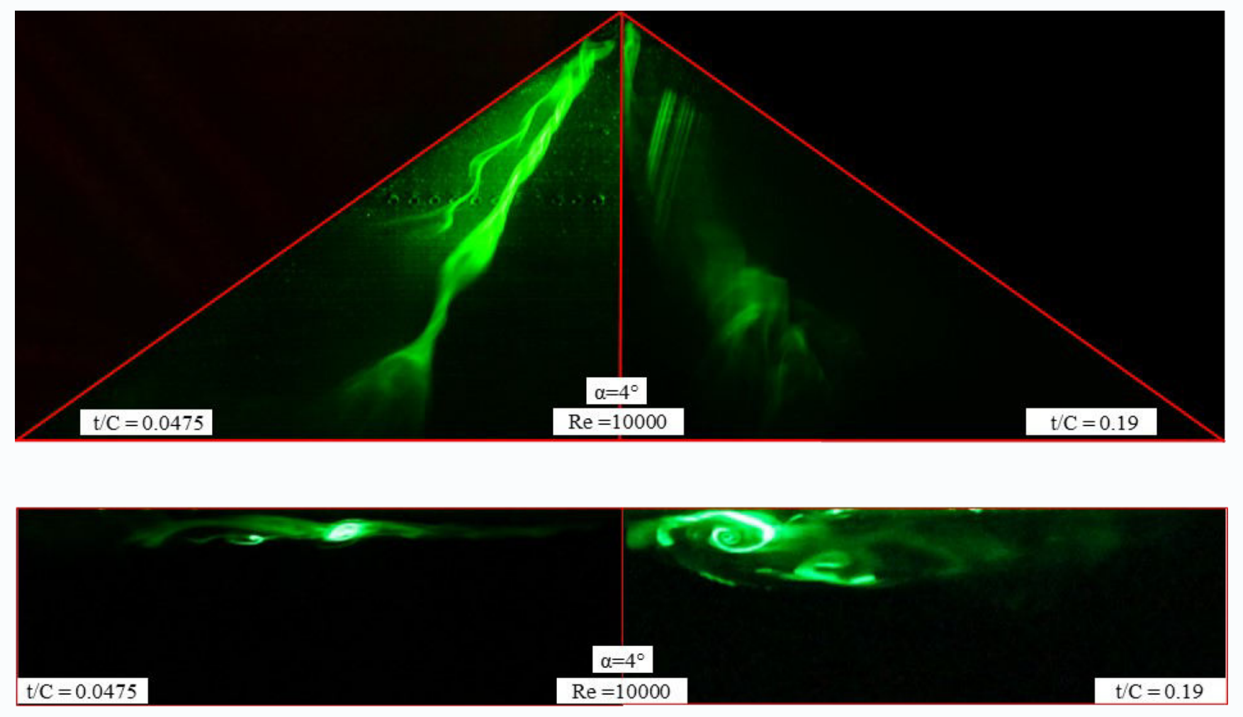

Figure 2. Effect of t/C ratio on flow structure of a 35 deg swept delta wing.*

Methodology:

Five different delta wing models with t/C ratios of 2, 3.3, 5, 10, and 15% were tested in a low-speed wind tunnel using laser illuminated smoke visualization, surface pressure measurements, particle image velocimetry, and force measurements.

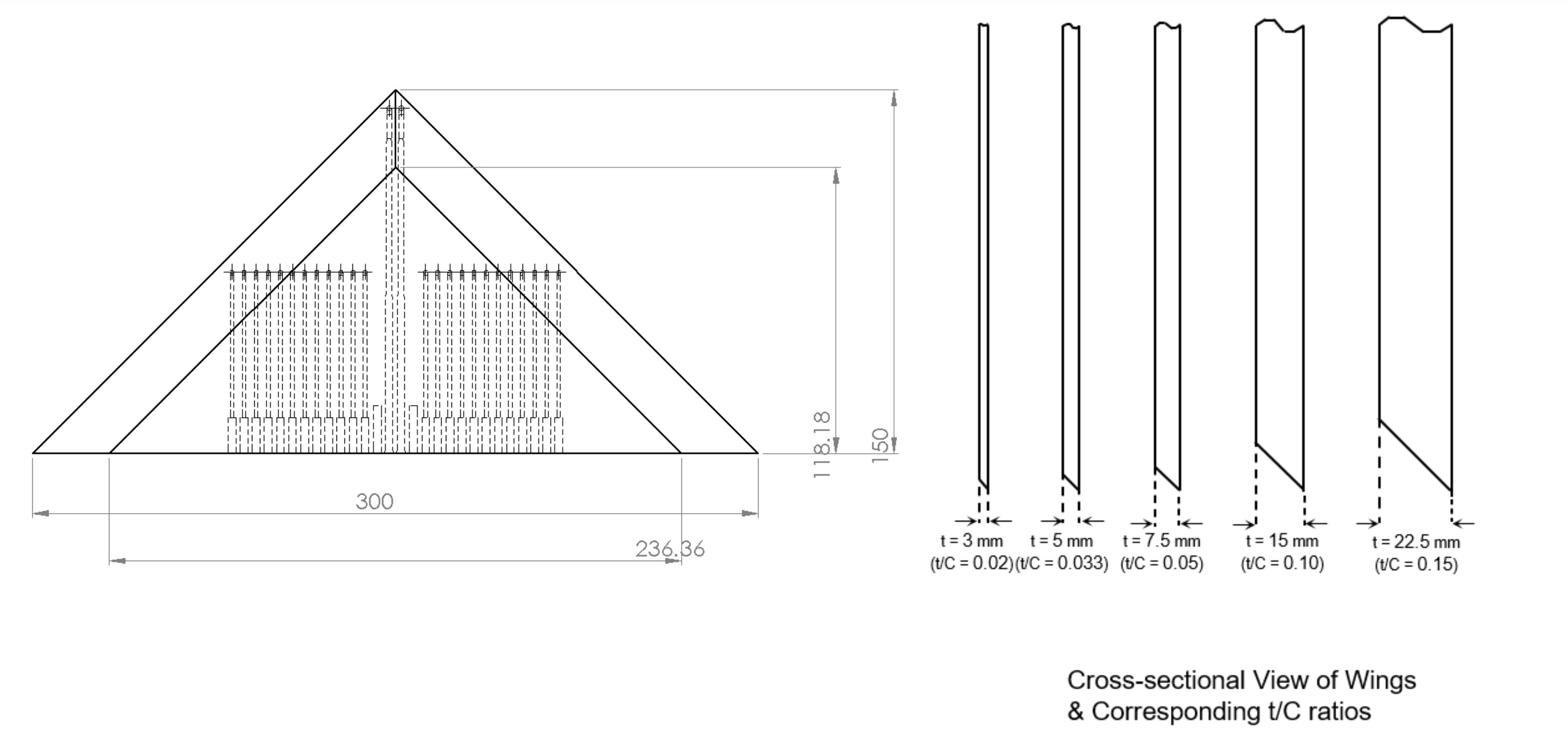

Figure 3. Schematic representation of the wing planforms.

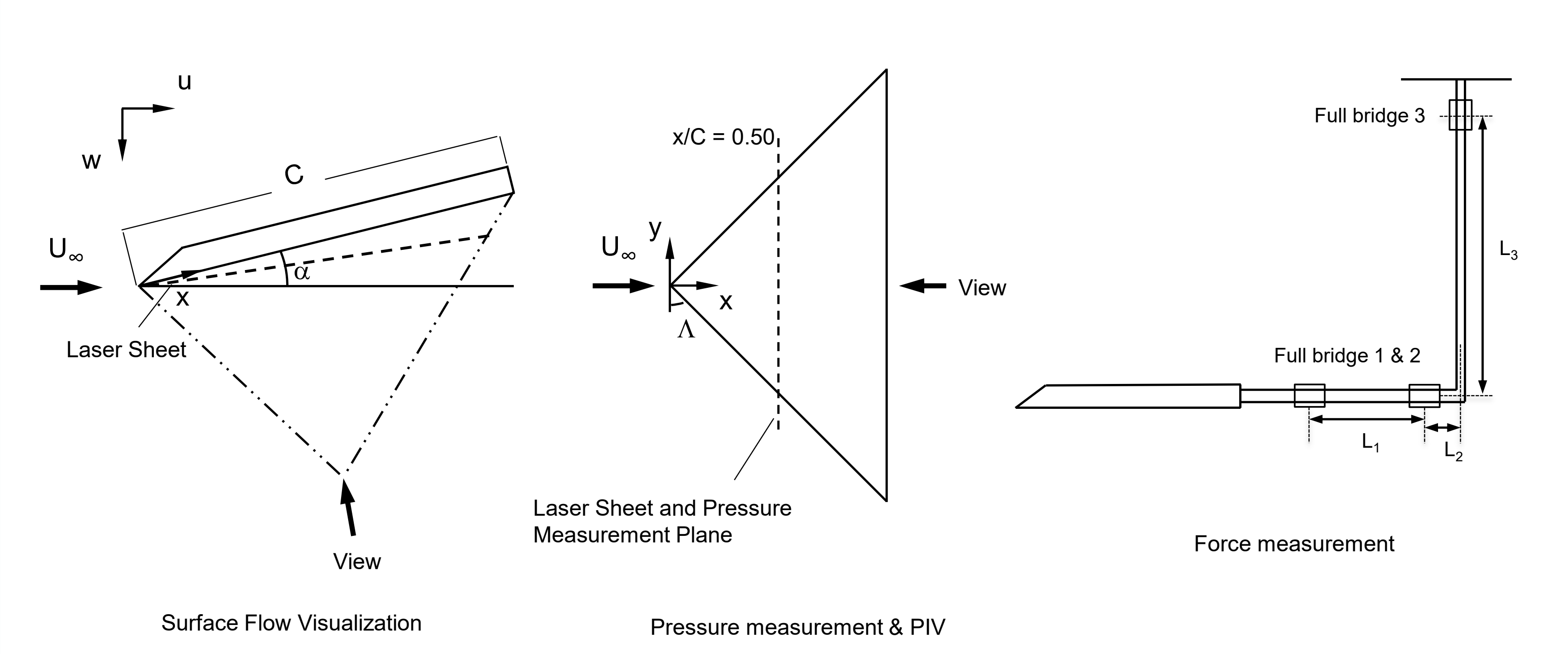

Figure 4. Schematic representation of the force measurement strut, pressure measurement plane, and laser sheet orientations for flow visualization and PIV.

Results:

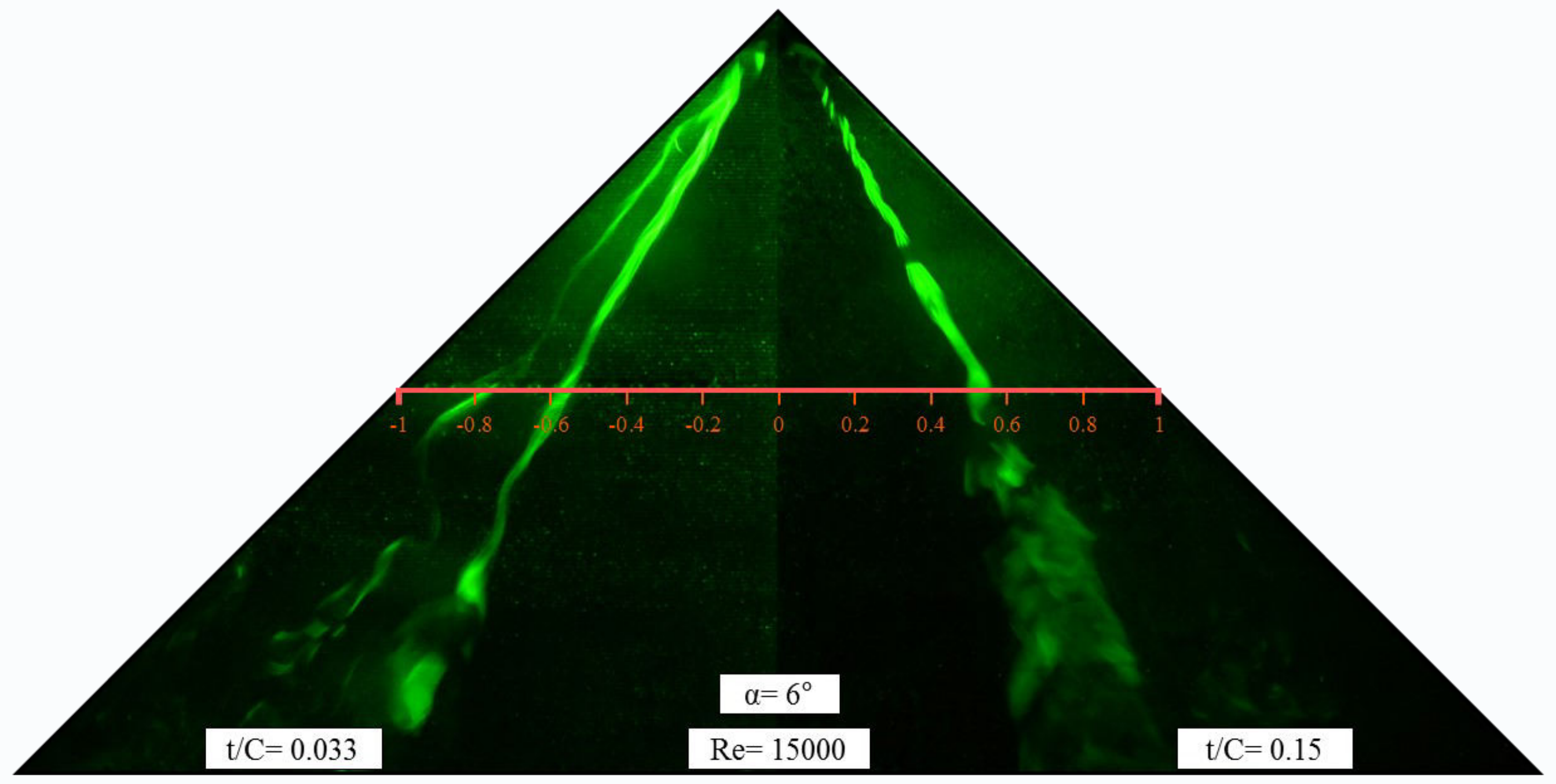

Figure 5. Laser-illuminated surface flow smoke visualizations of t/C = 0.033 and 0.15 for Re = 1.5×10^4 at angle of attack of α = 6 deg.

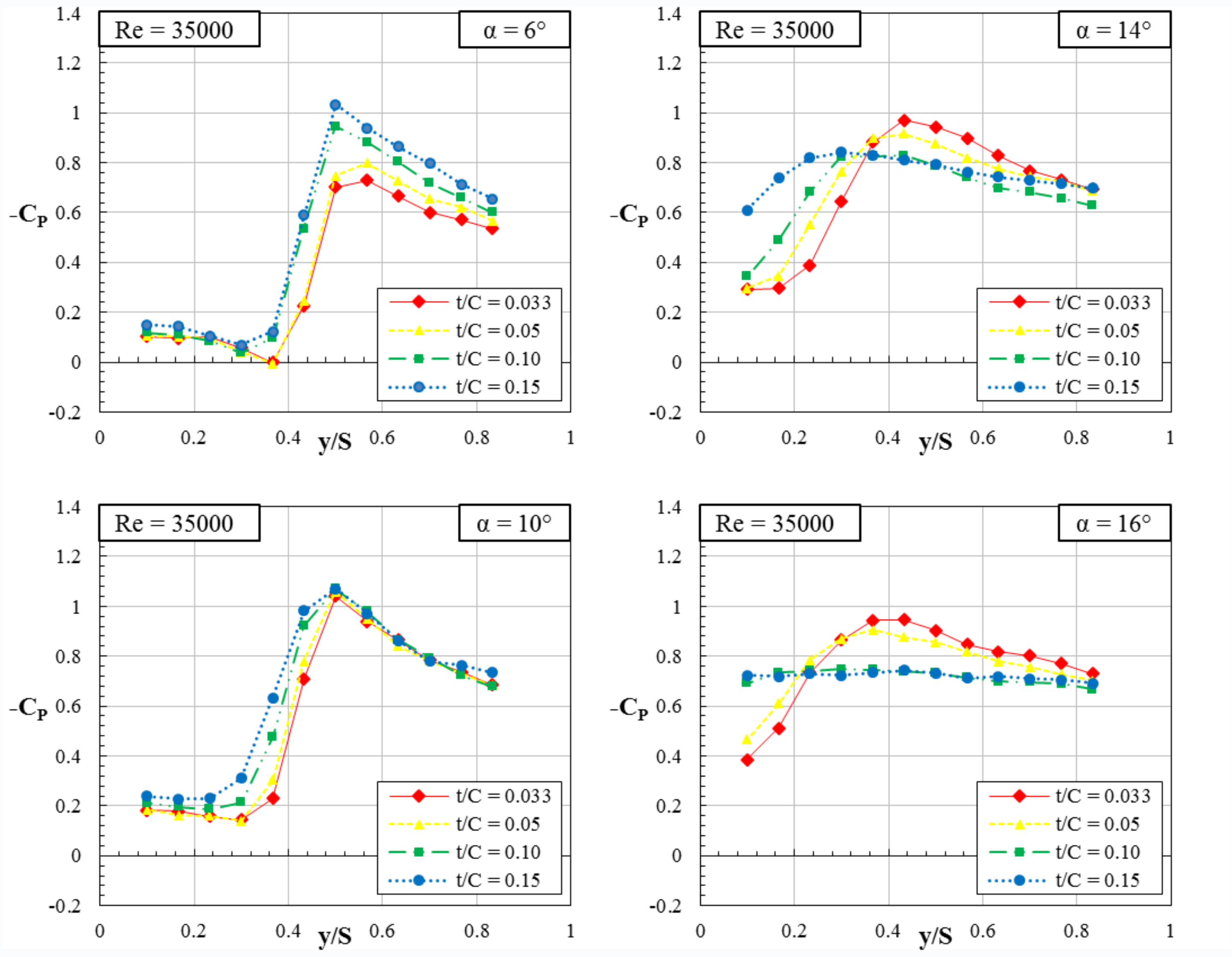

Figure 6. -C_p distributions of half span wing for t/C = 0.033, 0.05, 0.10, and 0.15.

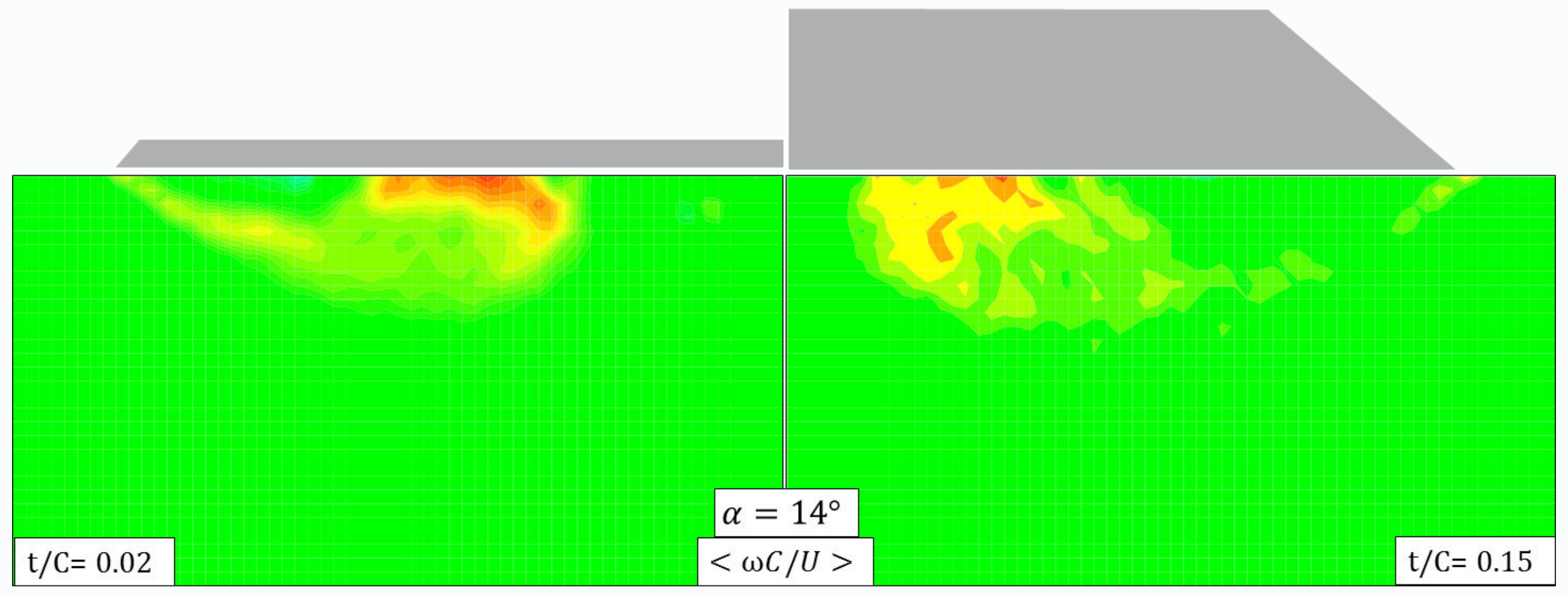

Figure 7. Constant contours of non-dimensional axial vorticity (ωC/U) at angle of attack of α = 14° and Re = 3.5×10^4 for t/C = 0.02 (left) and 0.15 (right).

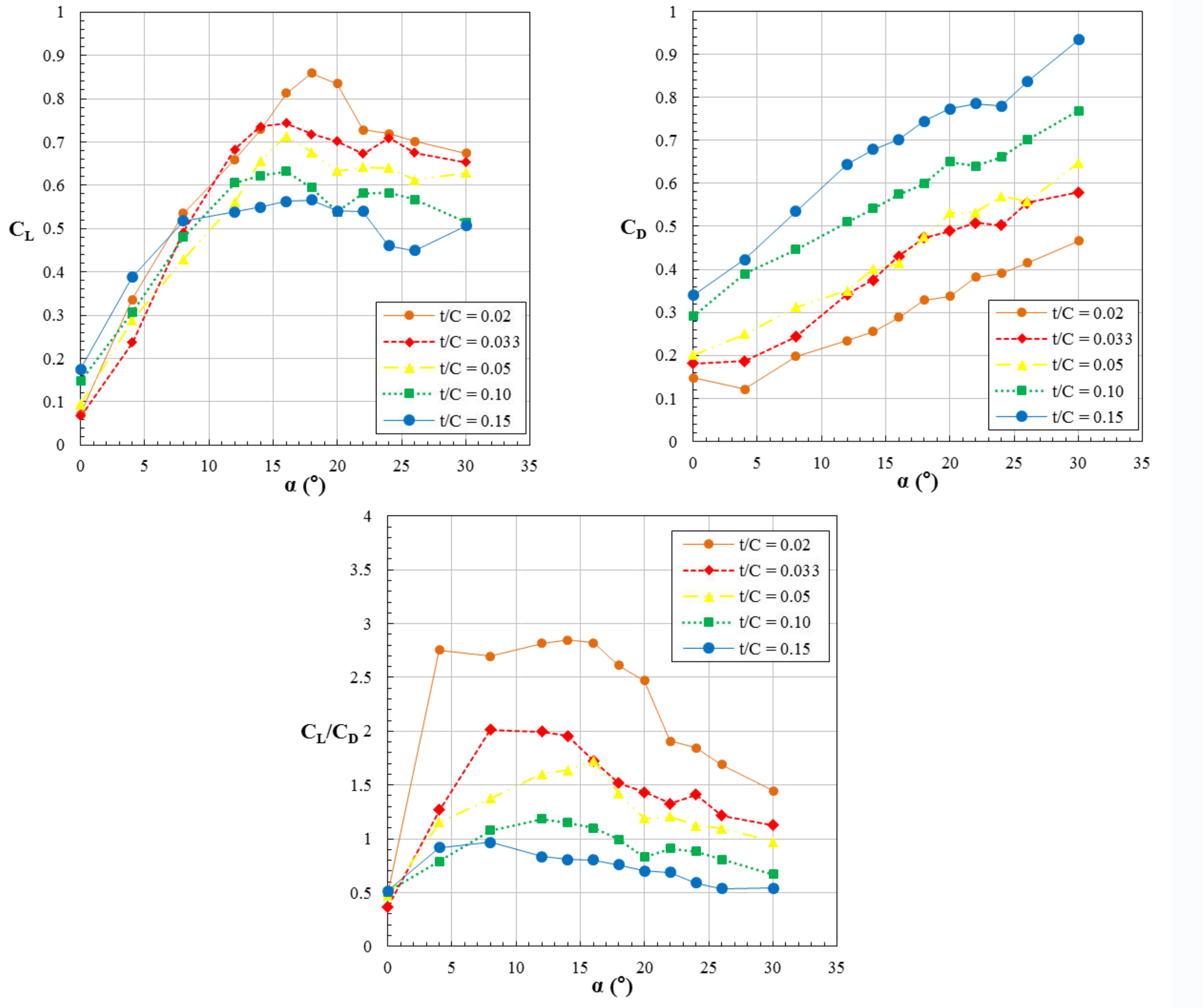

Figure 8. Lift coefficient C_L (top-left), drag coefficient C_D (top-right), and corresponding lift-to-drag ratio C_L/C_D (bottom) at Re = 3.5×10^4 .

Conclusions:

1) **The effect of t/C ratio on flow structure is substantial such that the formation of leading edge vortex and its corresponding breakdown location are considerably influenced by the t/C ratio. At relatively lower angle of attacks, the strength of the vortex structure increases as the t/C ratio increases. However, low t/C ratio wings have three-dimensional surface separations at significantly higher angle of attack compared to high t/C ratio wings.**
2) **The results of force measurements are quite in line with the results of velocity and pressure measurements. At low angles of attack, higher lift coefficients, C_L, are achieved as the t/C ratio increases. However, maximum C_L values that can be reached are higher and appear at higher angle of attack as the t/C ratio decreases. This indicates that the wing gets more resistive to the stall condition with decrease in t/C ratio. Considering the drag coefficient, C_D, and lift-to-drag ratio, C_L/C_D, increase in t/C ratio induces significant increase in C_D and significant drop in C_L/C_D values.**

*** Burak Gülsaçan, Gizem Şencan, and Mehmet Metin Yavuz. "Effect of Thickness-to-Chord Ratio on Flow Structure of a Low Swept Delta Wing"**