Effect of Thickness-to-Chord Ratio on Flow Structure of a Low Swept Delta Wing

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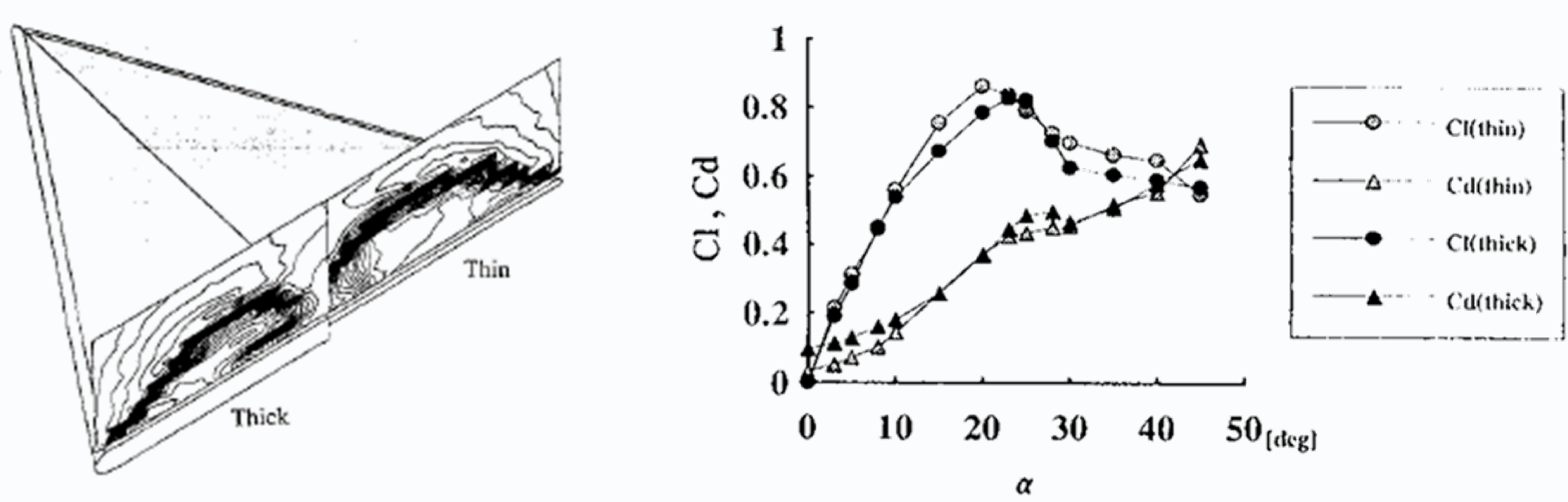
Motivation and Objective:

Increasing interest in micro air vehicles (MAV), unmanned combat air vehicles (UCAV) and unmanned air vehicles (UAV) for commercial and military purposes in recent years, attracts aerodynamicists to work on the enhancement of flow over nonslender delta wings, typically $\Lambda \leq 50$ deg, which can be considered as the simplified planforms of these vehicles.

The effect of thickness-to-chord (t/C) ratio has been studied in literature with particular interest in aerodynamic performance of high and moderate swept delta wings, where global flow fields on these wings have not been quantified and studied thoroughly. In addition, considering the low swept wings, no study focusing on t/C ratio has been reported. The present study aims to characterize the effect of t/C ratio on flow structure of a delta wing with sweep angle of 35 deg.



(a) (b)

Figure 1. Illustration of difference in (a) delta wing vortex formation and (b) lift & drag coefficients between thin and thick delta wings. (Kawazoe, H., et.al. 1994).

Methodology:

Experiments were conducted in a low speed wind tunnel using laser-illuminated smoke visualization, surface pressure measurement, and near surface and cross flow particle image velocimetry (PIV).

Four delta wing models, with the same sweep angle of 35 deg, chord length of 105 mm, and a bevel angle of 45 deg on the windward side, had the thicknesses of 5 mm, 10 mm, 15 mm and 20 mm with the corresponding thickness-to-chord ratios of 0.0475, 0.095, 0.1425 and 0.19 , respectively.

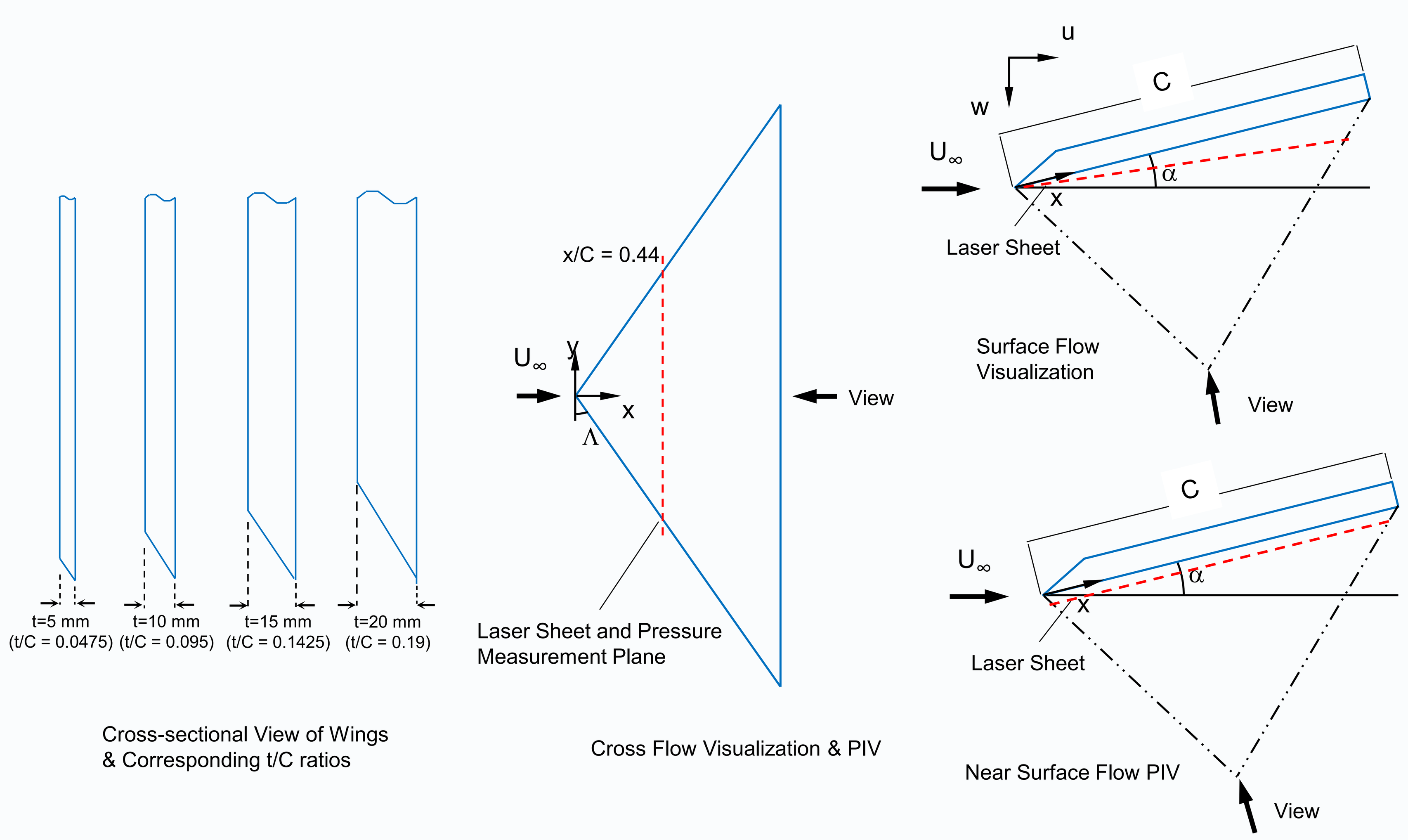


Figure 2. Schematic representation of the wing models including laser sheet orientations for flow visualization and PIV.

Results:

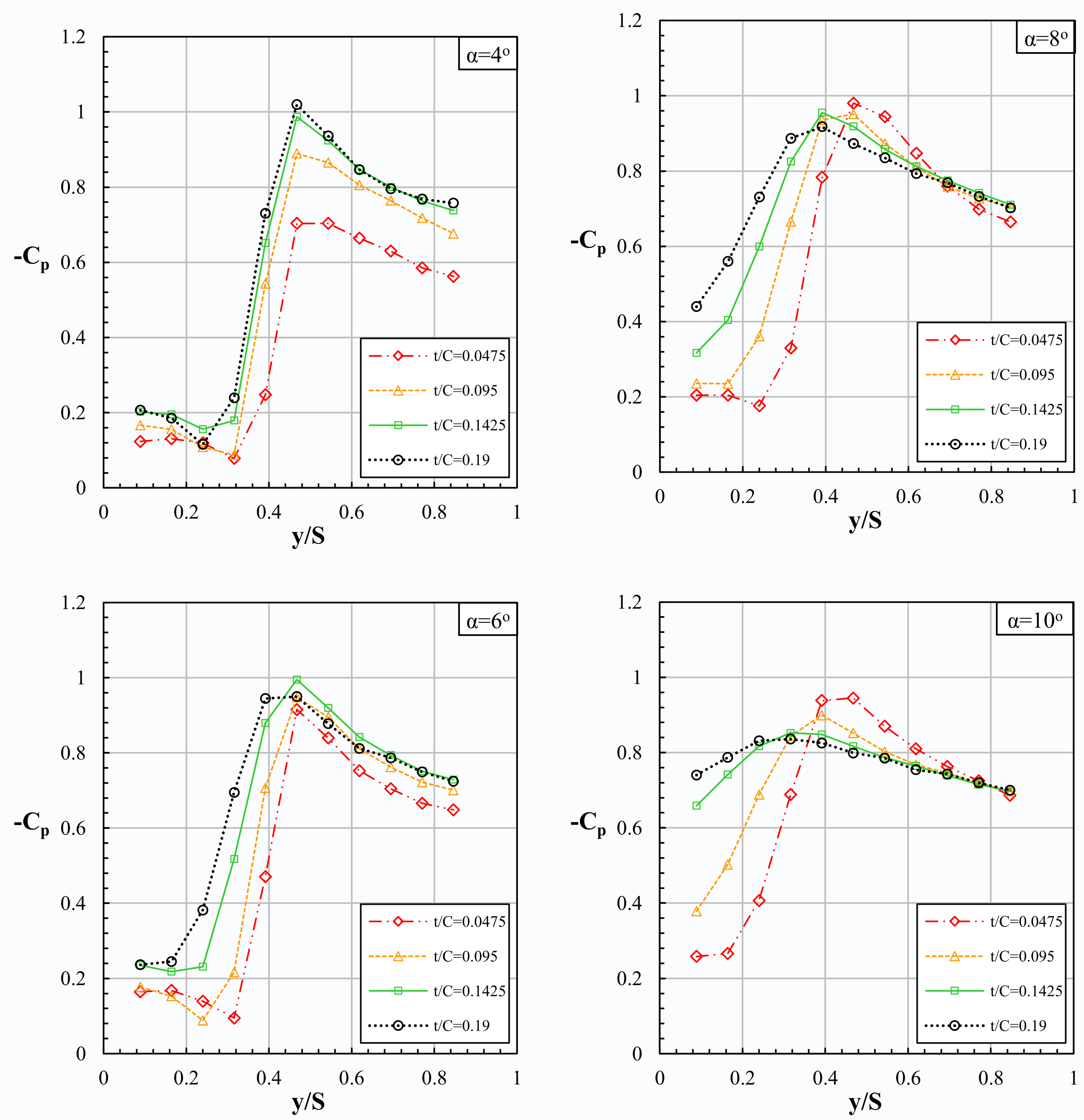


Figure 3. The dimensionless pressure distribution $-C_p$ with respect to dimensionless half span for t/C= 0.0475, 0.0095, 0.1425 and 0.19 at different attack angles

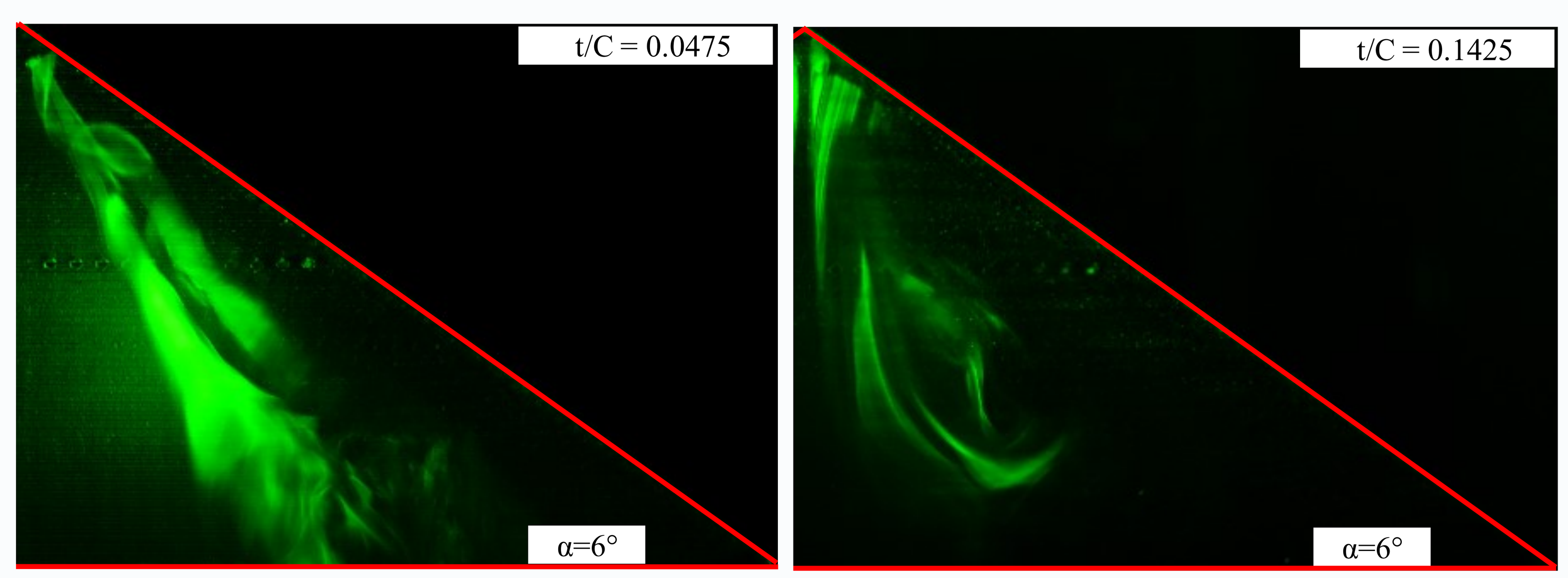


Figure 4. Laser-illuminated surface flow smoke visualizations of t/C= 0.0475 and 0.1425 for angle of attack of α= 6 deg at Re= 1.0 x 10^4

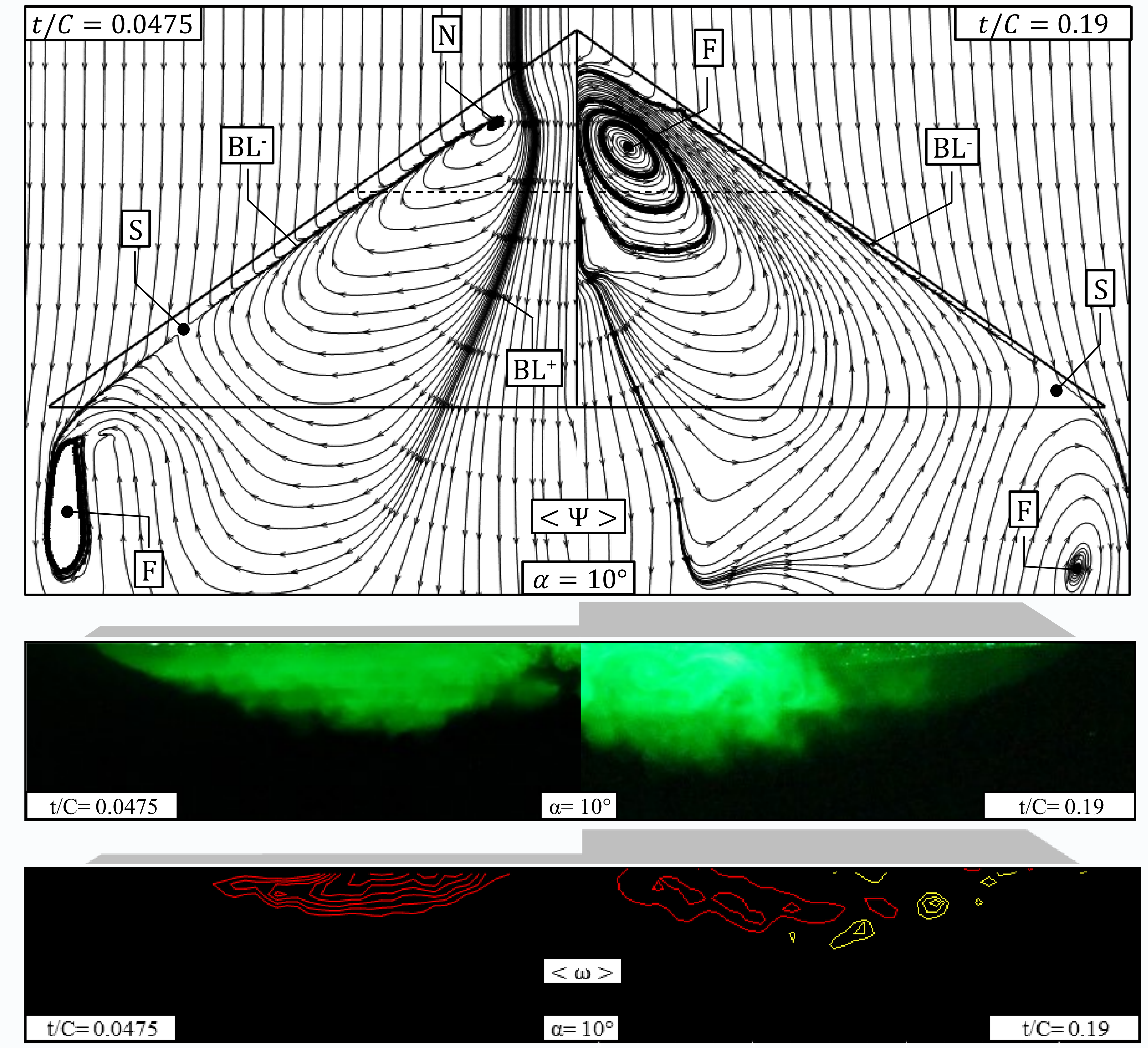


Figure 5. Comparison of patterns of time-averaged streamlines $\langle\Psi\rangle$ with cross flow smoke visualizations and constant contours of axial vorticity $\langle\omega\rangle$ for α= 10 at Re= 3.5 x 10^4:$[|\langle\omega\rangle|]_{min}$=200 s^{-1}, $\Delta\,[|\langle\omega\rangle|]$=100 s^{-1}.

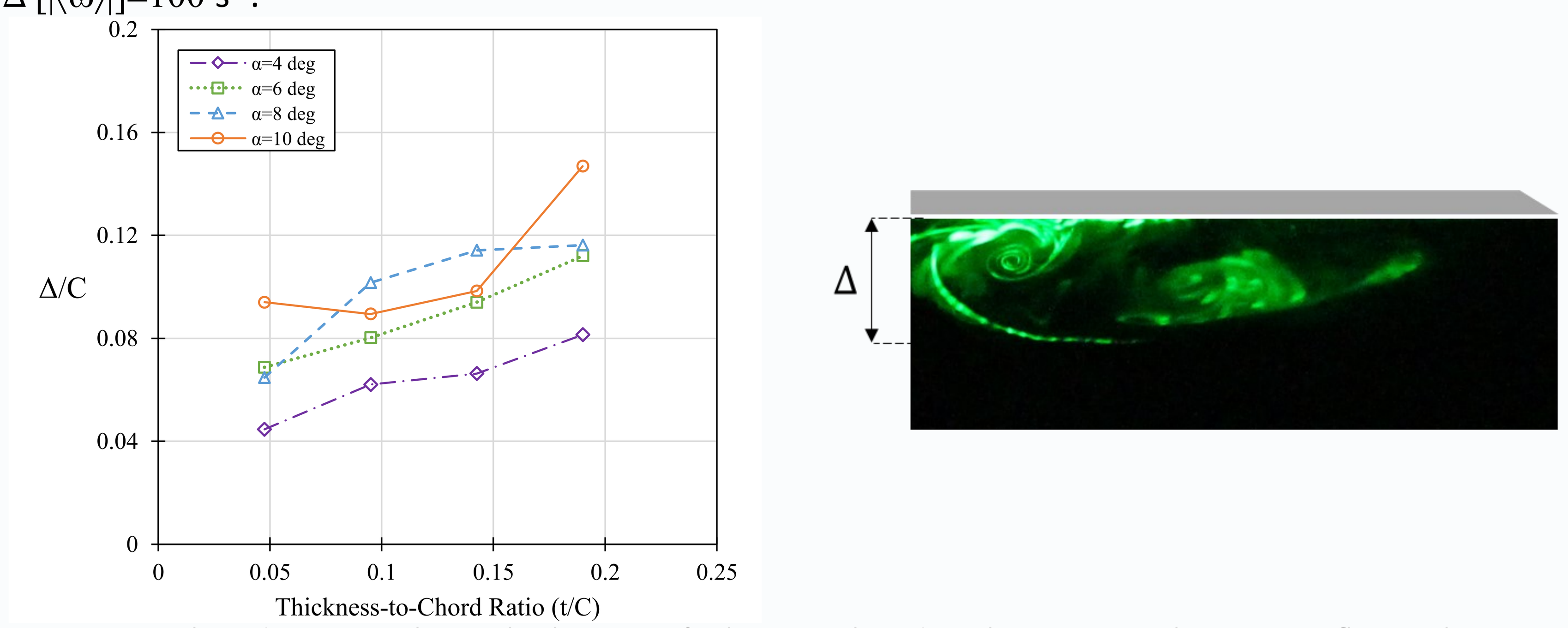


Figure 6. The dimensionless thickness of the smoke distribution in the cross flow plane at Re= 1.0 x 10^4 for t/C= 0.0475, 0.095, 0.1425 and 0.19 and α= 4, 6, 8 and 10 degrees

Conclusions:

1) At low attack angles, the strength of the leading edge vortices increases as the t/C ratio increases. This might suggest a better vortex-induced lift performance for high t/C ratio wing at low angles of attack.
2) The wing with t/C= 0.0475 has pronounced surface separation at higher attack angle compared to the wing with t/C= 0.19, which indicates that the lowest t/C ratio wing might be more resistive to the prestall and stall conditions.
3) The thickness of the smoke distribution in the cross flow plane is directly correlated with the wing thickness. This needs further investigation to draw conclusion on how this might effectively be utilized.