Predicting the Maximum-Lift Performance of Unmanned Combat Air Vehicle Planforms Using the Euler Equations

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Abstract

The current generation of Unmanned Combat Air Vehicle (UCAV) technology demonstrators (including the Northrop Grumman X-47B, Dassault nEUROn and BAE Systems Taranis) employ all-wing, edge-aligned configurations in order to reduce their radar cross section (RCS) characteristics. The highly-swept leading-edges of these configurations result in vortex-separated flows at moderate to high incidence angles, enhancing lift generation but resulting in substantially increased induced drag. The objective of the present study is to investigate the ability of inviscid-flow methods to predict the maximum-lift characteristics of such UCAV configurations. Figure 1(a) shows the two UCAV planforms considered, based around a generic 40^o edge-aligned configuration. Figure 2(b) shows the RCS characteristics for the two planforms, for head-on X-band radar illumination at 9 GHz, predicted using a finite-difference, time-domain solution of Maxwell's Equations. These indicate reduced overall RCS levels in all viewing directions, apart from a small number of spikes in directions determined by the planform geometric angles. Figure 2 presents the high-lift aerodynamic performance for the two configurations, as measured in low-speed wind tunnel tests using 1/20th scale models. Comparisons of integrated loads and moments with predictions using a vortex-lattice method show the inability of such an inviscid-flow method to predict maximum-lift conditions. However, an inviscid-flow method based on solution of the Euler equations demonstrates an ability to predict maximum-lift conditions, presumably as a result of breakdown of the separated, leading-edge vortices. Note that the magnitude of the maximum lift is better predicted for the configuration with a 60^o leading-edge strake. This suggests that the Euler equations give improved predictions as leading-edge sweep angle increases. Figure 3 compares predicted upper surface pressure contours for the two configurations, which indicate that the leading-edge, separated-vortex flow remains well-behaved up to larger incidence angles for the straked configuration. The paper will include comparisons of these predicted upper-surface flows with surface-flow visualisation studies carried out in the low-speed wing tunnel.

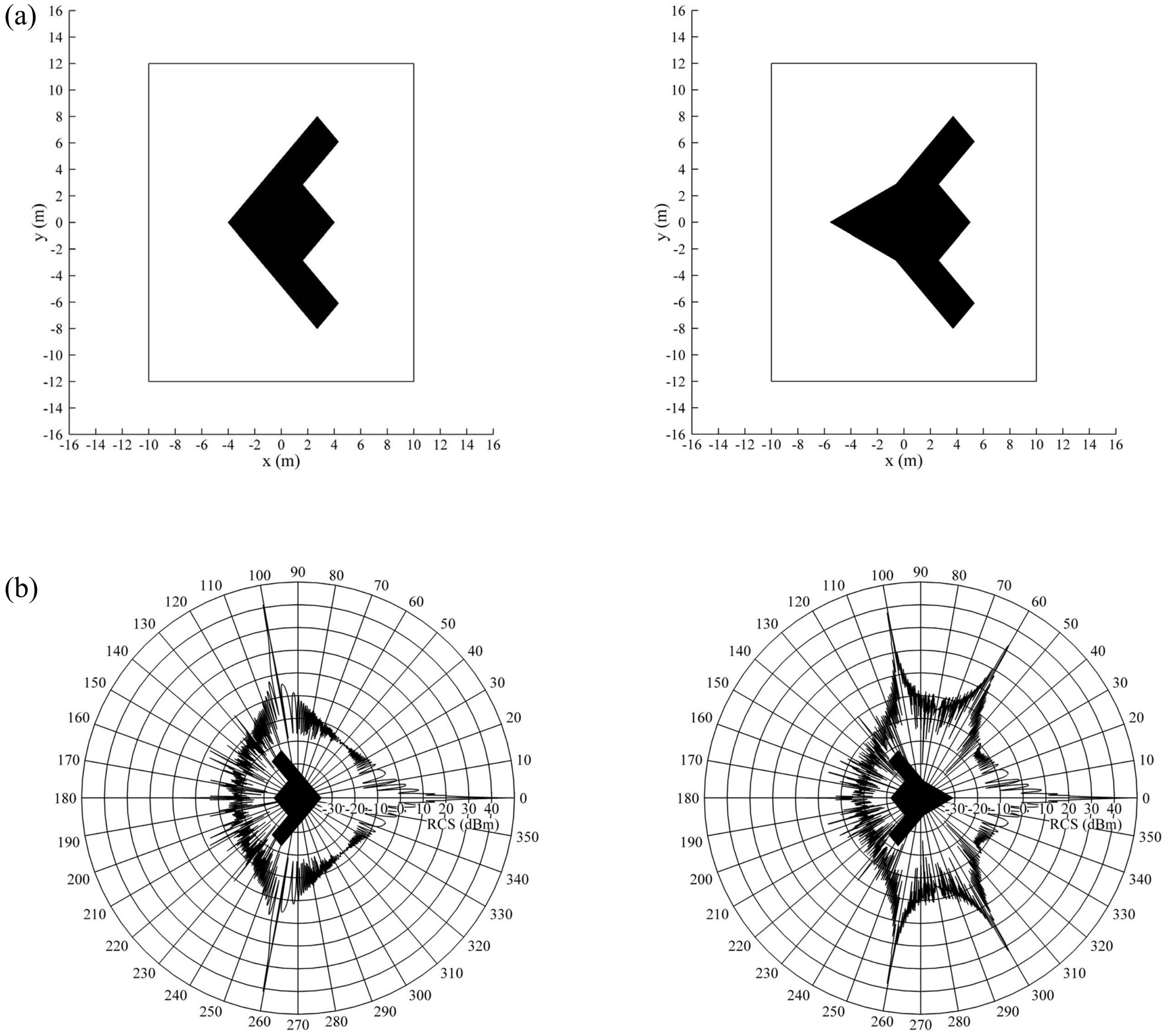

Figure 1 40^{o} UCAV and 40^{o} UCAV with 60^{o} Strake:
(a) Planform Geometries;
(b) RCS for Nose-On Illumination at 9 GHz

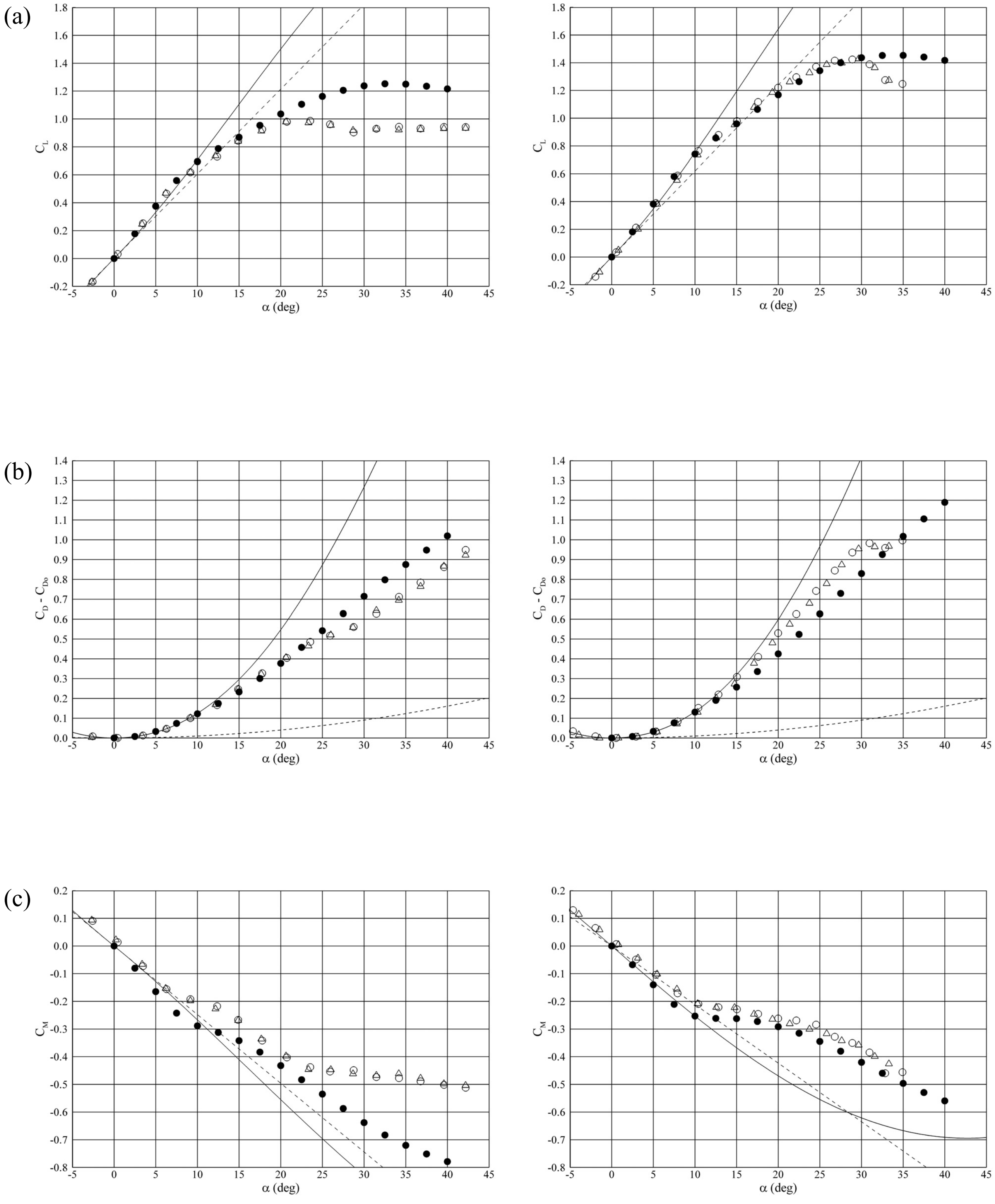

Figure 2 40° UCAV and 40° UCAV with 60° Strake:
(a) Lift Coefficient vs Incidence Angle;
(b) Induced-Drag Coefficient vs Incidence Angle;
(c) Pitching-Moment Coefficient vs Incidence Angle
○,Δ Experiment; - - - - Vortex-Lattice Method; ——— Vortex-Lattice Method with Suction Analogy; ● Euler Method

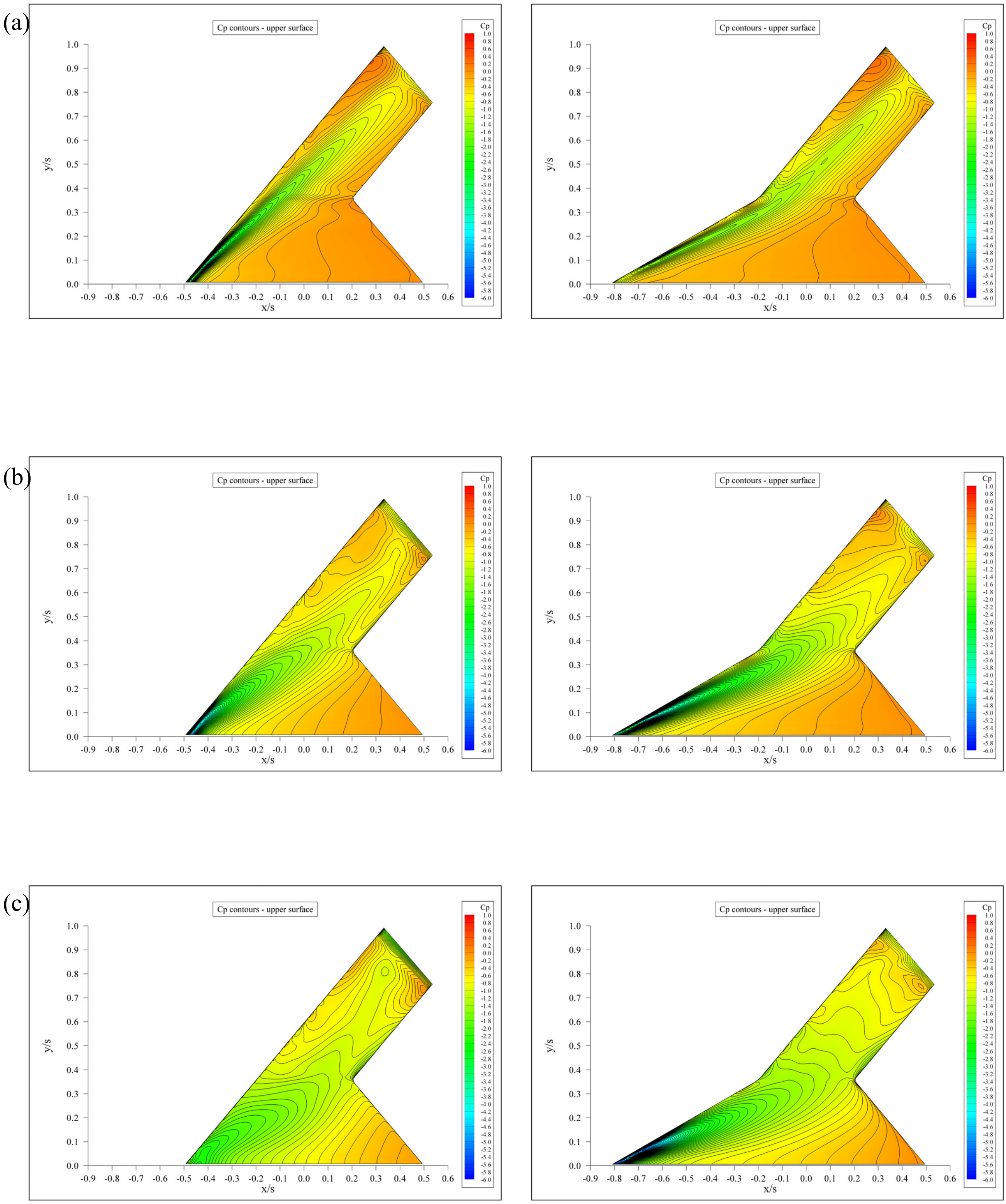

Figure 3 40° UCAV and 40° UCAV with 60° Strake:
Predicted Upper Surface Pressure Coefficient Contours – Euler Method
(a) Incidence Angle = 10°; (b) Incidence Angle = 20°;
(c) Incidence Angle = 30°