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NUMERICAL INVESTIGATION OF VORTICAL FLOWS OVER A CLOSE-COUPLED DELTA CANARD-WING CONFIGURATION

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Abstract. In this study, vortical flows over a close-coupled canard-wing-body configuration at high angle of attacks are studied by using an open-source RANS solver, SU^2. A grid study is first performed for delta wing only and close-coupled canard-wing-body configurations. Vortex structures, vortex breakdown, surface streamlines and surface pressure distributions are considered in the assessment of the vortical flow fields. The spanwise surface pressure distributions are favorably compared against the experimental and the numerical studies available in the literature. The parallel computational performance of SU^2 is also assessed.

1 INTRODUCTION

Modern fighter aircraft have high demands and requirements on rapid maneuverability reaching high angles of attack. Such requirements led to the studies on flows around delta wings at high angles of attack [1,3]. It is shown that there occur fundamental phenomena at high angles of attack such as vortex breakdown and flow separation which are essential reasons of loss of lift and increase of drag. It is also shown that vortex breakdown and flow separation can be delayed by inducing an additional vortex into the flow around body. One of the most effective ways of inducing an additional vortex into flow is a usage of close-coupled wing-canard configuration [4]. Close-coupled canard-wing configurations have been investigated in the past and canard-wing configurations are now widely employed on modern fighters (e.g. XFV-12A, SAAB Gripen, or European Fighter Aircraft).

The vortical flow over a delta wing at high angle of attacks shows a nonlinear behavior due to the formation of strong leading edge vortices and its break-down over the wing Characterizing such flows is rather difficult and highly challenging. In the past, various experimental[5,9] and numerical[10,12] studies are conducted in order to understand the

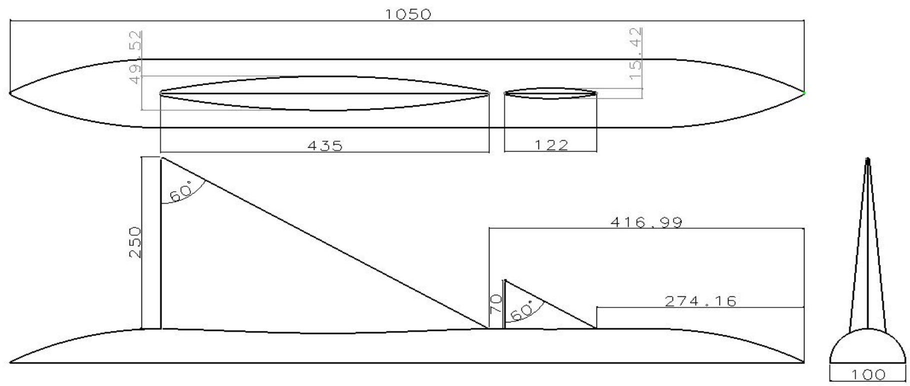

Figure 1: Canard-wing-body configuration

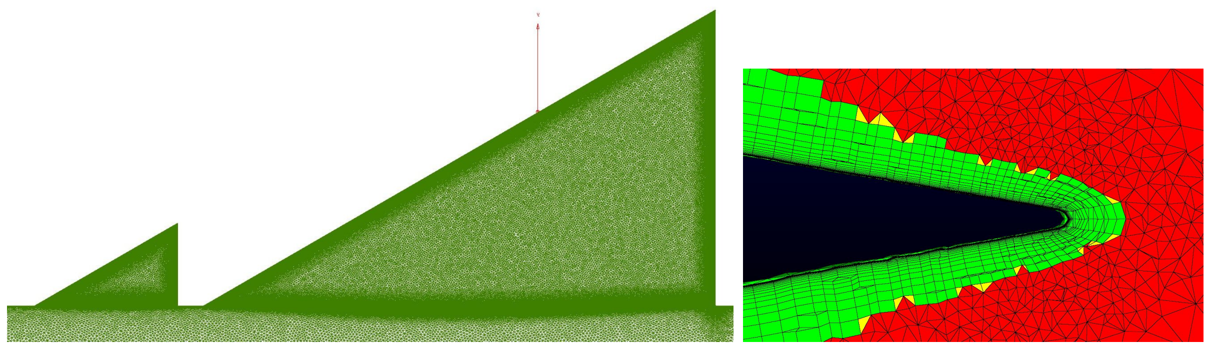

Figure 2: Hybrid grid distribution over the surface and around the leading edge of the wing

aerodynamic characteristics of close-coupled wing-canard configurations at high angle of attacks.

In this study, SU^2 is employed for the solution of flow fields over a close-coupled canard-wing configuration. SU^2 is an open-source unstructured flow solver and turbulent flows are described by the Reynolds-averaged Navier-Stokes equations (RANS)[11]. SU^2 is initially developed at Stanford University, and still being developed by a world-wide community. The solver currently has Spalart-Allmaras (SA) and $k-\omega$ SST turbulence models. Verification studies are first performed on a configuration studied experimentally and numerically. The solid modeling of sharp corners and grid densities needed to resolve vortical flows are experimented. The parallel performance of SU^2 is also assessed.

2 PRELIMINARY RESULTS

In this study the configuration given in Hummel's experiments[9] is considered for validation purposes. The model dimensions used in the experimental study are exactly taken and the flow fields are computed at $M = 0.117$ and $Re = 1.4{\cdot}10^6$. The sharp leading edges are slightly rounded. Figure 1. shows the configuration studied. Canard-off and canard-on configurations are both considered.

Following the verification studies, a steady flow field is obtained over the canard-wing

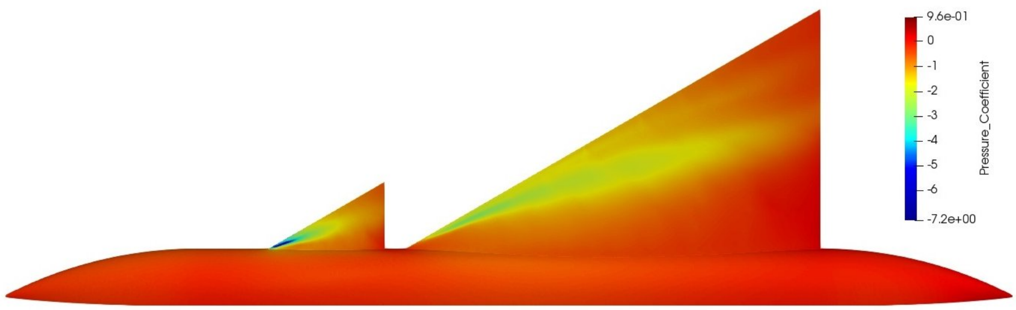

Figure 3: Surface pressure distribution at $Re = 1.4{\cdot}10^6$, $\alpha = 20°$

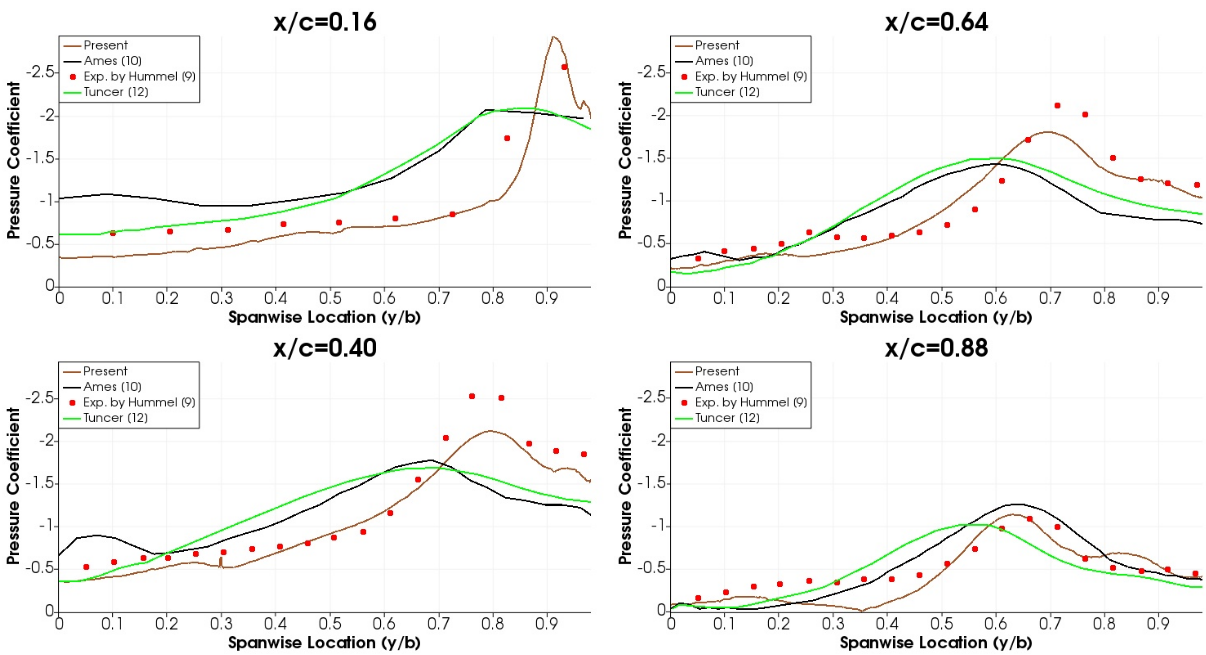

Figure 4: spanwise presure distributions at $Re = 1.4{\cdot}10^6$, $\alpha = 20°$

body configuration at 20°angle of attack for $Re = 1.4{\cdot}10^6$. The convective fluxes are evaluated by JST model, the SA turbulence model and the Jacobi linear solver are employed. The computational grid (Figure 2) consists 8.5 million tetrahedral and 7.5 million prismatic cells, a total of 16 million cells. The hybrid grid has a y^+ value of about 1. A typical computation on a 128/2 core/node parallel computing environment takes about 30 wall-clock hours.

Figure 3. shows the upper surface pressure distribution for the canard-on configuration, where the suctions created by leading edge vortices are clearly observed. In addition, Figure 4. shows the spanwise pressure distribution on the wing upper surface. As seen, the present results are in a better agreement with the experimental data than the reference numerical studies performed in 90s. Yet, the vortex strength is underpredicted in the mid-chord location. It appears that the volume grid distribution at the mid-chord location is

still coarse.

In the full paper, the effects of grid resolution, turbulence models and flux methods will be presented in detail. The solutions for canard-on and canard-off configurations will be performed and the effectiveness of canard will be assessed quantitatively.

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