Numerical Simulation of Flow Past a Prolate Spheroid

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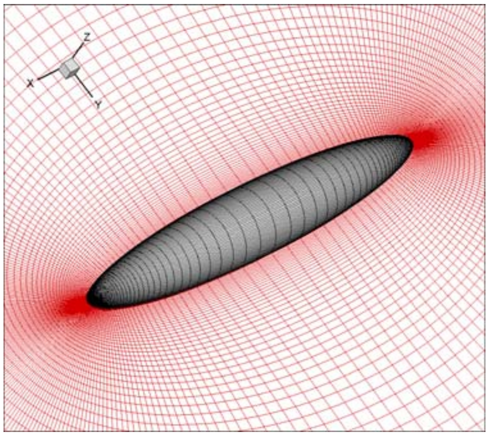
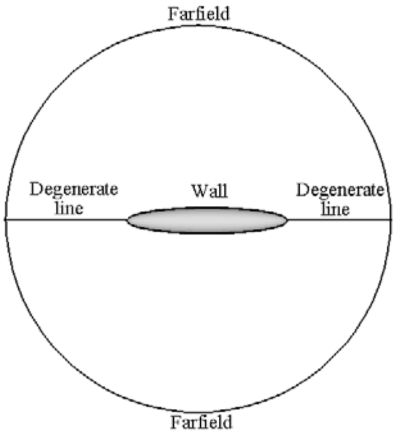
ABSTRACT

The prolate spheroid is geometrically very simple but the flow characteristics are complex which are dominated by transition and three-dimensional separation phenomenon having both primary and secondary vortex. The transition phenomenon in this flow is triggered due to the stream wise Tollmien-Schlichting (T-S) wake instability and cross flow instability, which makes the prediction more challenging due to lack of effective predictive tool to model transition.

The present work aims at simulating numerically the three-dimensional turbulent flow past 6:1 prolate spheroid at Re=4.2 x 10^6 using RANS approach for which experimental data are available in literature. These simulations have been carried out using parallel version of the in-house multiblock structured incompressible flow solution code 3D-PURLES (**3D P**ressure based **U**nsteady **R**eynolds Average Navier Stokes and **LES** solver). The present simulation uses O-O grid topology consisting of 111 x 101 x 312 grid points covered by 24 blocks and having near wall $y^+ < 1$. The typical view of the grid and boundary conditions used for the present analysis are shown in Fig. 1. The time accurate computations have been carried out using the central difference scheme for spatial discretisation of convective flux and a second order accurate scheme for temporal discretisation with the non-dimensionalised time step size of 0.05. The simulations have been carried out using SST turbulence model assuming the flow to be fully turbulent. The convergence criteria has been fixed to be 10^{-4} for the continuity and momentum equations at every time step.



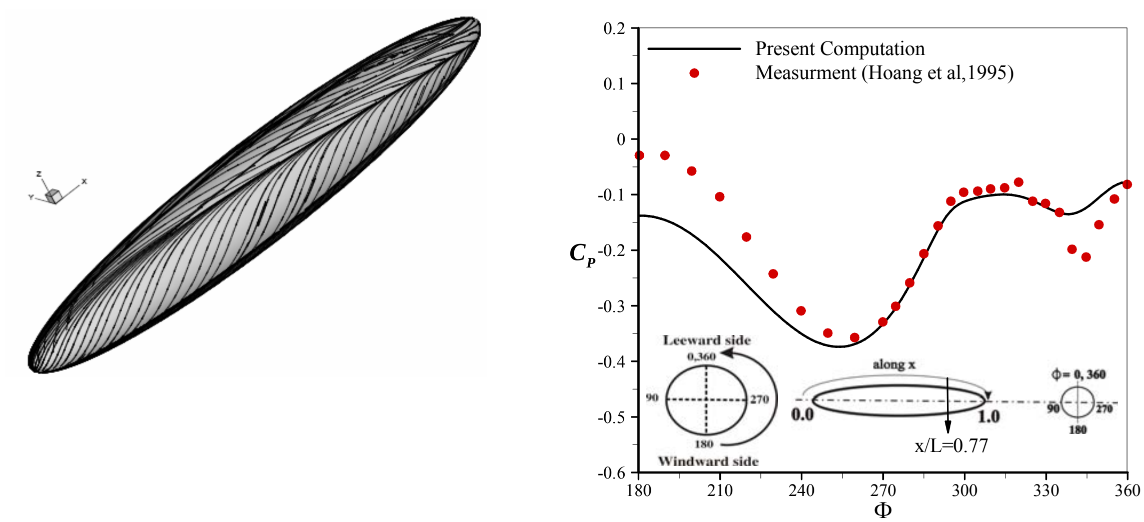
(a) Near wall grid



(b) Boundary conditions

Fig 1. Near wall grid and boundary conditions for flow past prolate spheroid

The computed surface streamline (skin friction lines) for α = 20^0 is shown in fig 2.(a). A strong primary separation on the leeward surface is observed to be initiated near the nose region followed by a well developed secondary vortex due to substantial divergence of streamlines from windward to leeward side. The azimuthal variation of computed surface pressure at α=20^0 at axial location *x/L* = 0.77 is compared with the measurement data of Hoang *et. al*. and shown in fig 2 (b). The figure shows that the present computation matches reasonably well in the leeward side (Φ = 270^0 - 360^0) and deviates from the measurement in the windward side (Φ = 180^0 - 270^0). The computations could also capture both the minima as observed in the experiment but the second minimum (at Φ = 345^0) is under predicted. In full paper, effect of grid size will be attempted and effect of transition will be studied by fixing the transition location or by using the k_T-k_L-ω model.



(a) Surface streamlines

(b) Azimuthal variation of the pressure distribution at axial location x/L = 0.77

Fig 2: Flow past prolate spheroid for α = 20^0, *Re* = 4.2 × 10^6, SST Model

Keywords: Prolate Spheroid, turbulent flow, separated flow.

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