CASE STUDY

SHOCK-VORTEX INTERACTIONS IN TRANSONIC FLOW OVER A DELTA WING AIRCRAFT

The Delta wing forms a critical component in various applications involving high-speed flight. Vortex breakdown in the delta wing is accompanied by a sudden change in the pressure distribution and has a detrimental effect on the aerodynamic characteristics. In particular, transonic flow conditions in delta wings at a moderately high Angle of Attack (AoA) give rise to complex interactions between shock waves and the leading-edge vortex system. Further complications are caused by localized supersonic flow regions over the wing.

This work investigates the onset of vortex breakdown under transonic flow over a 65^0 swept-back delta wing with a sharp leading edge. We carried out simulations using the higher order Entropic Lattice Boltzmann Method (ELBM) for transonic flows, developed at SankhyaSutra Labs (SSL) at AoA of 23.6^0.

The computational domain used in the simulations is $15C_r \times 6C_r \times 6C_r$, where C_r is the root chord of the wing measuring 65.364 cm. To reduce the computational resources needed, the simulations are performed with a symmetry boundary condition along the longitudinal plane. The no-slip boundary condition is applied over the surface of the delta wing. A Mach number of 0.85 (transonic flow) is chosen along with a Reynolds number of 6×10^6, calculated based on the mean aerodynamic chord of 43.576 cm.

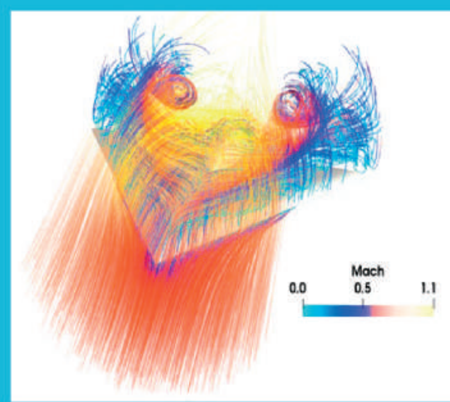

Figure 1 Streamlines coloured by Mach number capturing the vortical flow and localised supersonic regions

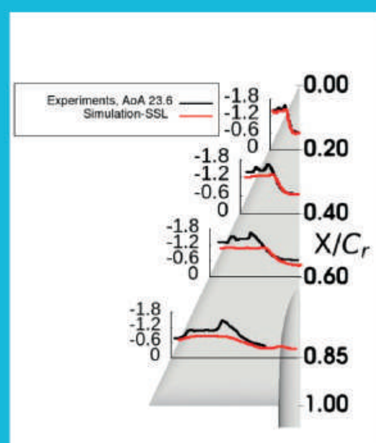

Figure 2 Coefficient of pressure distribution against experimental data at AoA = 23.6°

The simulation results are compared against the experimental database from Langley National Transonic Facility (NTF) Qualitative and quantitative comparisons are made with experimental data to understand the phenomenon of shock-vortex interactions with the ELBM solver. The sharp leading edge and the slender body cause the flow to separate early, which leads to a primary vortex that dominates the upper surface of the wing. This can be observed from the streamlines plotted in Figure 1. Supersonic structures are shown at the core of the primary vortex.

Simulation results are validated by comparing the pressure distribution with experimental data . Figure 2 shows the pressure distribution at selected chord wise locations over the wing.

Simulations show a good match in the suction peak close to the apex of the wing. Values further downstream exhibit slight under-prediction, overall pressure distribution matches well with the experiments.

One of the major challenges with existing CFD solvers is the ability to detect secondary vortex and cross flow shock over the delta wing in transonic flow conditions. Well established experimentally, capturing the same in simulations has been a challenge. The solver from SSL has not only successfully captured the pressure losses, secondary vortex structures and the presence of terminating and cross-flow shocks over the wing platform, but has also demonstrated a good match with experimental data.

Further Reading: Milind D et. al., Transonic flow over Delta Wing using Entropic Lattice Boltzmann Method, 33rd Congress of the International Council of the Aeronautical Science, Sweden, 2022;

About SankhyaSutra Labs

SankhyaSutra Labs provides high-fidelity multiphysics and aerodynamics simulation software that leverages highly efficient computational methods, complemented by an optimally architected High Performance Cluster (HPC) to achieve reliable simulation. Our tools find applications primarily in aerospace and defence, automotive, semiconductor manufacturing, and process industries during many phases of the product lifecycle including design, operation, and maintenance. The technology also enables fundamental insights into physical phenomena including fluid dynamics, heat transfer, chemical reactions and particle dynamics. Digital twins developed using SankhyaSutra's technology are key enablers of Industry 4.0.

Incubated in 2015, SankhyaSutra Labs has its R&D centre in Bangalore with target customers across the globe. The name SankhyaSutra literally translates to 'numerical algorithms' in Sanskrit. SankhyaSutra Labs is a subsidiary of Jio Platforms Limited, which is a subsidiary of Reliance Industries Ltd.