CASE STUDY

ENTROPIC LATTICE BOLTZMANN METHOD FOR STALL ANALYSIS

Due to high computational requirements of Direct Numerical Simulation (DNS), engineers and scientists use the Reynolds-averaged Navier-Stokes (RANS) method, where the mean flow is solved with an appropriate turbulence model for closure of Reynolds shear stress. RANS can provide reliable and accurate results for a variety of flows but fails to generalize to all flow conditions. For example, in the presence of large-scale unsteadiness in the mean flow, like the flow stalling over an airfoil, most of the turbulence models give erroneous results. The Lattice Boltzmann method is a mathematical formulation which can be used to overcome the technical limitations of RANS, while providing a high-fidelity solution with much lower memory requirements than DNS.

In this study, we look at stall analysis of an Eppler airfoil (E387) at a Reynolds number of 3×10^5 using SankhyaSutra Taral, which is based on higher-order entropic lattice Boltzmann method (ELBM). ELBM is developed to address the stability issues by adhering to the discrete H-theorem which is equivalent to the second law of thermodynamics in kinetic theory. SankhyaSutra Taral uses higher order

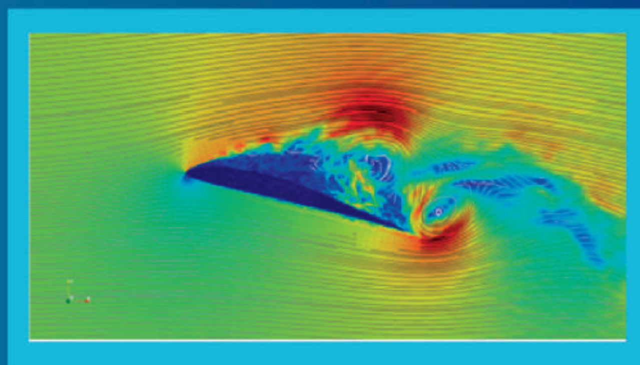

Fig. 1 Instantaneous velocity flow field at stall conditionUAV simulation

LB model on a Body Centred Cubic (BCC) lattice.

The computational domain is $8.5c \times 5c \times 0.2c$, where c is the chord of the airfoil. The simulation is performed at a stall angle of 16° in accordance with the experimental data.

The qualitative flow field at angle of attack (AoA) of 16^0 is shown in Fig. 1. The flow separates at the leading edge causing the airfoil to stall. The separated rolls are seen in the instantaneous streamline plot. The coefficient of pressure for the simulation is shown in Fig. 2. On the pressure side of the blade, the coefficient of pressure matches quite well with the experiments.

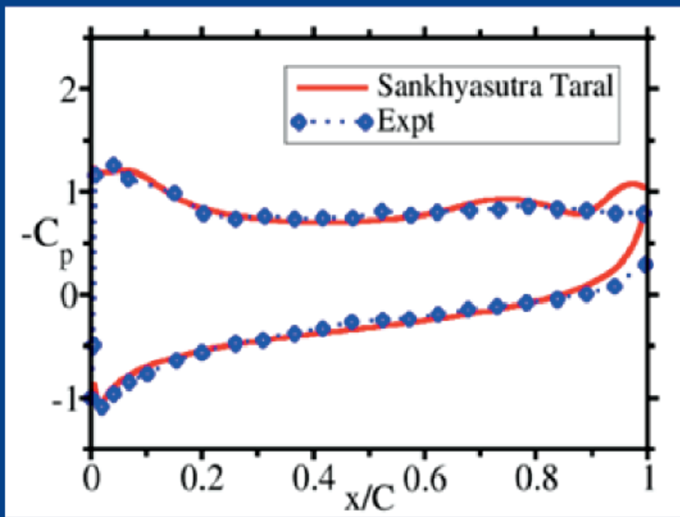

Fig. 2 Coefficient of pressure

On the suction side there is a good match with the experiments while a discrepancy can be noted near the trailing edge for x/C greater than 0.85. The difference can be attributed to the low frequency oscillation in the flow at stall.

The case study has demonstrated the ability of ELBM to accurately predict separation by simulating flow past the Eppler airfoil in stall regimes. All the simulations presented here do not use any explicit turbulence model to capture the flow dynamics.

Further reading: S. A. H. Rizvi, C. Thantanapally, S. Arcidiacono, and S. Ansumali. “Numerical simulation of separated flows using entropic lattice Boltzmann method”. *AIAA Scitech 2023 Forum.*

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.