Turbulent Flow Simulation of a Confined Square Jet using LatticeBoltzmann Method

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Overview

This study presents a Large Eddy Simulation (LES) of a confined turbulent square jet at a Reynolds number of Re = 1.84×10^5, conducted to investigate the flow dynamics and turbulence structures. The jet is bounded by four lateral walls, which play a significant role in the evolution of vortical structures and the overall mixing process. Such simulations are crucial for understanding confined turbulent jets encountered in aerodynamics, propulsion systems, and industrial mixing processes.

Simulation Setup:

The simulation is done using an in-house developed solver written in Fortran language based on the Simplified Lattice Boltzmann method (SLBM). The constant Smagorinsky model is used for turbulence closure. To accelerate the computation, the solver is parallelised for GPU execution using the OpenACC standards. The code is compiled by the `nvfortran` compiler provided with the NVIDIA HPC SDK. The simulation was run on a NVIDIA A100 GPU card hosted at the PG Senapathy Computer Centre. The computational domain contains 8.6 million grid points, requiring 10.7 GB of GPU memory and the simulation ran for about 45 hours.

Simulation Results:

The results presented below illustrate the instantaneous velocity field and vortex structures downstream of the jet exit, capturing the highly three-dimensional and chaotic nature of the confined jet.

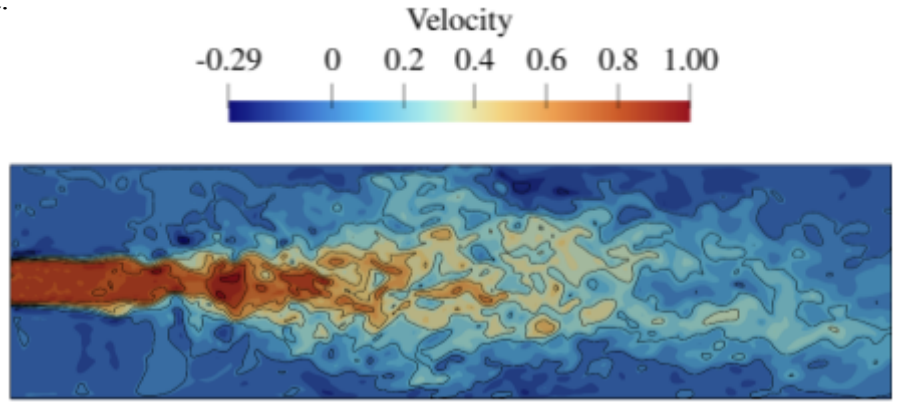

Fig 1: Contours of velocity magnitude

Initially the jet displays a smooth laminar-like behavior up to a downstream distance of approximately four times jet width. Beyond this point the jet violently breaks down into a number of smaller vortical structures, showing a rapid transition to turbulence. These vortices improve the mixing characteristics which is favourable for applications involving heat transfer.

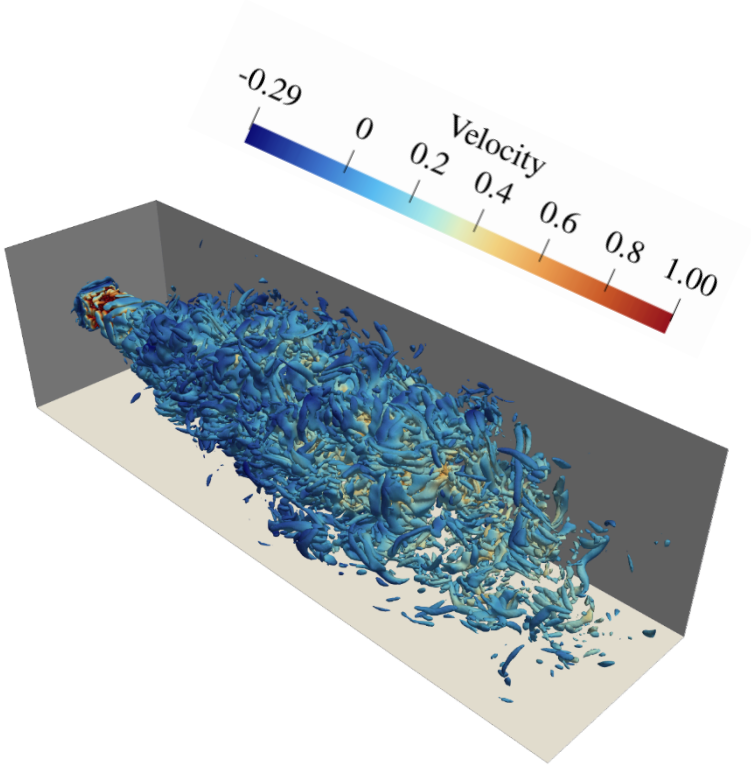

Fig 2: Iso-surfaces of Q-criterion coloured by velocity magnitude

References

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