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COMPARING KINETIC ENERGY PRESERVING AND GODUNOV SCHEMES ON THE FLOW AROUND A NACA0012

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For the numerical resolution of the compressible Navier-Stokes equations (NS) with Finite Volumes (FV) two main approaches have called the attention of researchers and engineers. First, following the hyperbolic nature of the compressible NS equations, the Godunov-like schemes discretize the numerical fluxes by a characteristic analysis. Second, disregarding the hyperbolicity of the equations, the Kinetic Energy Preserving (KEP) or skew-symmetric discretizations are in accordance with the differential convective and diffusive operators properties.

The hyperbolic nature of the Navier Stokes equations in compressible flows has been widely studied in the past [1]. Upwind schemes are preferred due to the physical background of compressible fluids (wave-like behavior), but they suffer from errors associated with artificial numerical diffusion. The necessary grid refinement that makes insignificant this artificial diffusion is often impracticable for engineering applications, especially for unsteady 3D turbulent flows [2]. The introduction of anti-diffusive terms by high-order schemes helps to alleviate this problem. Godunov's methods are often related to transonic and supersonic cases and their applicability on subsonic Direct Numerical Simulations (DNS) and Large Eddy Simulations (LES) is to be explored.

On the other hand, KEP-like schemes are mostly focused on the resolution of subsonic turbulent flows. For these, it has been shown to be essential to avoid the artificial diffusion arising from any upwind-like schemes. Ducros et al. [3] developed skew-symmetric flux schemes that reduced aliasing errors, other authors (e.g. [4]) have focused on the conservation of kinetic energy. Resulting schemes have been added artificial diffusion to reduce wiggles and ensure stability at transonic regimes. Baez Vidal et al. [5] used small wavelength filters in order to do this while not affecting larger scales.

This work aims to help clarify the scope of Godunov-like and KEP-like methods by means of DNS of a NACA0012 airfoil at a moderate angle of attack, moderate Reynolds and various Mach numbers, ranging from nearly incompressible to supersonic. It will provide quantitative information on the scope of each of the aforementioned schemes on aerodynamics. Moreover, after some discrepancies between Jones et al. [6] and Rodríguez et al. [7] on the stall AoA of this airfoil the present work will also help to determine their cause.

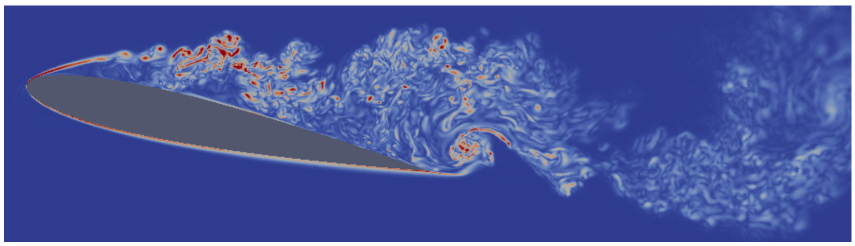

Figure 1: Intantaneous vorticity around NACA0012 at $Re = 50000$, $Mach = 0.1$ and $AoA = 12°$.

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