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Prediction of Finned Projectile Aerodynamics Using a Lattice-Boltzmann Method CFD Solution

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Abstract : In this paper, the prediction of the aerodynamic behavior of the flow around a Finned Projectile will be validated using a Computational Fluid Dynamics (CFD) solution, XFlow, based on the Lattice-Boltzmann Method (LBM). XFlow is an innovative CFD software developed by Next Limit Dynamics. It is based on a state-of-the-art Lattice-Boltzmann Method which uses a proprietary particle-based kinetic solver and a LES turbulent model coupled with the generalized law of the wall (WMLES). The Lattice-Boltzmann method discretizes the continuous Boltzmann equation, a transport equation for the particle probability distribution function. From the Boltzmann transport equation, and by means of the Chapman-Enskog expansion, the compressible Navier-Stokes equations can be recovered. However to simulate compressible flows, this method has a Mach number limitation because of the lattice discretization. Thanks to this flexible particle-based approach the traditional meshing process is avoided, the discretization stage is strongly accelerated reducing engineering costs, and computations on complex geometries are affordable in a straightforward way. The projectile that will be used in this work is the Army-Navy Basic Finned Missile (ANF) with a caliber of 0.03 m. The analysis will consist in varying the Mach number from M=0.5 comparing the axial force coefficient, normal force slope coefficient and the pitch moment slope coefficient of the Finned Projectile obtained by XFlow with the experimental data. The slope coefficients will be obtained using finite difference techniques in the linear range of the polar curve. The aim of such an analysis is to find out the limiting Mach number value starting from which the effects of high fluid compressibility (related to transonic flow regime) lead the XFlow simulations to differ from the experimental results. This will allow identifying the critical Mach number which limits the validity of the isothermal formulation of XFlow and beyond which a fully compressible solver implementing a coupled momentum-energy equations would be required.

Keywords : CFD, computational fluid dynamics, drag, finned projectile, lattice-boltzmann method, LBM, lift, mach, pitch
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