NUMERICAL SIMULATIONS OF THE FLOW AROUND A SPINNING PROJECTILE IN SUBSONIC REGIME

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Abstract— **The unsteady flow around a 155 mm projectile governed by the Navier-Stokes (NS) equations is numerically solved with a Large Eddy Simulation (LES) scheme, together with the SubGrid Scale (SGS) solved by a Smagorinsky model and the van Driest near-wall damping. The computed results are obtained in the subsonic flow regime for a viscous and incompressible Newtonian fluid in order to determine the axial drag coefficient, and they are validated against experimental data. The problem was solved by a monolithic finite element code for parallel computing on a Beowulf cluster.**

Keywords— **spinning projectile model, incompressible subsonic flow, large eddy simulation (LES), finite element method, fluid mechanics.**

I. INTRODUCTION

There are two main factors to distinguish projectile aerodynamics from classic aerodynamics. The first one is the fact that most projectiles have an axis or plane of symmetry, which implies also symmetric aerodynamic parameters. The second one is related to large spinning velocities that, for tube artillery, are from 5,000 to 10,000 Revolutions per Minute (*RPM*), generating aerodynamic effects which are present only in the aeroballistic area. Among these particular parameters, there are the force and the torque produced by the Magnus effect. Although this force is relatively lower than the lift and can be ignored, the torque is critical for the projectile stability (Silton, 2002).

In general, a conventional artillery spinning projectile counts on a central cylindrical body to be guided through the cannon tube, and a frontal ogive whose length measures from one and a half to three times the caliber, see Fig. 1, resulting in a configuration with a drag higher than other flying corps, and where most of the drag force is due to the pressure. It is important to notice that this geometry places the pressure center ahead of the gravity center, see Fig. 2, that would make the projectile overturn if it were not stabilized. The mechanism used for avoiding the overturn is the spinning, i.e. the projectile is launched with an appropriate rotational velocity given around its longitudinal axis. This rotational velocity is generated during the travel of the object through the cannon tube due to the interaction between the rotating band and the rifling inside the cannon tube. Under the conditions described, any destabilizing torque over the projectile makes it react with a rotation over a plane normal to the torque plane, originating nutation and precession. The first of them is quickly damped, whereas the second holds during the rest of the trajectory, but it is restricted by design to 5° or less around the translational direction.

The flow around a projectile presents turbulent boundary layers, whose separation is a usual phenomena, and a large turbulent wake formed at the bottom of the object. In ballistic aerodynamics, prevention or control of the separation of the boundary layer is one of the most important aims, as well as an appropriate ogive design. Typical velocities for field artillery projectiles are from 150 m/s to 900 m/s or even more, reaching subsonic, transonic or supersonic flow regimes around them. Then, a complete characterization should consider appropriate analysis tools for each of them, as those employed in Sahu (1991) and Weinacht (2003).

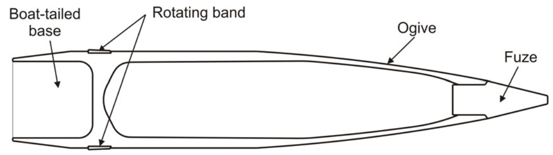

Figure 1: Relevant projectile parts.

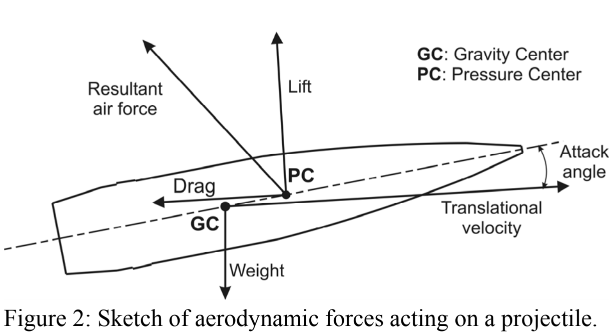

Figure 2: Sketch of aerodynamic forces acting on a projectile.