Influence of the Transonic Crossing for Precision Ammunition

Véronique de Briey *
Royal Military Academy, Brussels, Belgium

Benoit Marinus†
Royal Military Academy, Brussels, Belgium

Marc Pirlot‡
Royal Military Academy, Brussels, Belgium

I. Abstract

The trend for precision ammunition is always to hit a smaller target with a higher probability at an ever increasing distance. The last two decades revealed many new calibers, new weapon features and a large number of trajectory software to reach this goal. However, there is no unanimous criterion yet to define properly and scientifically why a projectile is better than another one. The existing software are often drag based (point-mass models), with a fitting established to match real firing, but they do not account specifically for the sharp changes in aerodynamic forces when the projectiles reach the transonic zone. Nonetheless, the transonic domain has to be crossed by precision ammunition when reaching high operational ranges with the classical propulsion and its inherent velocities. Some aero-ballistic articles define the transonic regime as a region of critical aerodynamic behavior where aerodynamic coefficients have been found to increase by as much as 100% for classical small caliber ammunition [1, 2].

This study will focus particularly on the .338 inch Lapua Magnum projectile, in operational use with Belgium Defense snipers. Depending on the brand, those .338 projectiles become subsonic between 1000 m and 1200 m, but the hit expectation for this weapon system is around 1600 m. The geometrical specificities of this projectile and the velocity range from Ma 1,2 to Ma 0,8 will be aerodynamically analyzed using Computational Fluid Dynamics (CFD), to understand better how does this projectile behave through the transonic domain. A 6-DOF Model [3] will then be used to assess properly the effect on the trajectory compared to a standard drag-based model (2-DOF), already optimized for this type of projectile.

Numerous CFD studies were achieved for all flight regimes to characterize spin-stabilized projectiles [4–13], some of them focused on the transonic regime [1, 2, 14–17]. Those references are used to validate our methodology on a 5,56 mm projectile. Aerodynamic force and moment coefficients will be obtained using steady Reynold Average Navier-Stokes simulations with a low-order turbulence model including transition (γ-SST k-ω-model [18, 19]) and validated against available data.

An extensive study including CFD, wind tunnel and spark-range firings was also done by the Army Research Laboratory (ARL) [20–22] to see the influence of rifling grooves on different 5,56 mm projectiles in the supersonic domain. The effort made to take the grooves in consideration experimentally and in CFD does not yield a significant improvement in that flight domain. Based on those results, further CFD investigations will however be continued on the .338 projectile in the transonic range, to assess the sensitivity of this specific precision ammunition to the grooves in that regime.

*PhD candidate, Dept of Weapon Systems and Ballistics of the Royal Military Academy, veronique.debriey@dymasec.be.
†Associate Professor, Dept of Mechanical Engineeering of the Royal Military Academy.
‡Professor, Dept of Weapon Systems and Ballistics of the Royal Military Academy.

References

[1] Nietubicz, C., Sturek, W., and Heavey, K., "Computations of Projectile Magnus Effect at Transonic Velocities," *AIAA Journal*, Vol. 23, No. 7, July 1985, pp. 998–1004. doi:10.2514/3.9030.

[2] Sahu, J., "Numerical Computations of Transonic Critical Aerodynamic Behavior," *AIAA Journal*, Vol. 28, No. 5, May 1990, pp. 807–816. doi:10.2514/3.25123.

[3] Mc Coy, R. L., "Modern Exterior Ballistics," 1999, Schiffer Publishing Ltd. : Atglen, PA.

[4] Sturek, W., "Boundary-Layer Studies On Spinning Bodies Of Revolution," *Ballistic Research Laboratory Technical*, 1973.

[5] Sturek, W., and Schiff, L., "Computations of the Magnus Effect for slender bodies in supersonic flow," *Ballistic Research Laboratory Technical Report*, September 1981. doi:10.2514/6.1980-1586.

[6] Weinacht, P., Sturek, W., and Schiff, L., "Navier-Stokes Predictions of Pitch-Damping for Axisymmetric Shell Using Steady Coning Motion," *Army Research Laboratory Technical Report*, September 1994.

[7] Park, S. H., Kim, Y., and Kwon, J. H., "Prediction of Damping Coefficients Using the Unsteady Euler Equations," *Journal of Spacecraft and Rockets*, Vol. 40, No. 3, 2003, pp. 356–362. doi:10.2514/2.3970.

[8] Cayzac, R., Carette, E., Thépot, R., and Champigny, P., "Recent Computations and validations of projectile unsteady aerodynamics," *22nd International Symposium on Ballistics*, 2005, pp. 2–9.

[9] Despirito, J., and Heavey, K., "CFD Computation of Magnus Moment and Roll Damping Moment of a Spinning Projectile," *AIAA Atmospheric Flight Mechanics Conference and Exhibit*, 2006. doi:10.2514/6.2004-4713.

[10] Weinacht, P., and Sturek, B., "Navier-Stokes Predictions of Pitch Damping for Axisymmetric Projectiles," *Journal of Spacecraft and Rockets*, Vol. 34, No. 6, Dec 1997, pp. 753–761. doi:10.2514/2.3306.

[11] Garibaldi, J., Storti, M., Battaglia, L., and Delía, J., "Numerical simulations of the flow around a spinning projectile in subsonic regime," 2007.

[12] Silton, S., "Navier-Stokes Predictions of Aerodynamic Coefficients and Dynamic Derivatives of a 0.50-cal Projectile," *29th AIAA Applied Aerodynamics Conference*, American Institute of Aeronautics and Astronautics, Honolulu, Hawaii, 2011. doi:10.2514/6.2011-3030.

[13] Sahu, J., "Virtual Fly-Out Simulations of a spinning Projectile from Subsonic to Supersonic Speeds," *29th AIAA Atmospheric Flight Mechanics Conference*, 2011. doi:10.2514/6.2011-3026.

[14] Sahu, J., "Transonic Navier-Stokes Computations for a spinning body of revolution," *Ballistic Research Laboratory Technical Report*, September 1991.

[15] Silton, S., "Navier-Stokes Computations for a Spinning Projectile From Subsonic to Supersonic Speeds," *Journal of Spacecraft and Rockets*, Vol. 42, No. 2, 2002, pp. 223–231. doi:10.2514/1.4175.

[16] Simon, F., Deck, S., and Guillen, P., "Zonal-Detached-Eddy Simulation of Projectiles in the Subsonic and Transonic Regimes," *AIAA Journal*, Vol. 45, No. 7, 2007, pp. 1606–1619.

[17] Sahu, J., "Computations of unsteady aerodynamics of a spinning body at Transonic Speeds," *27th AIAA Applied Aerodynamics Conference*, June 2009. doi:6.2009-3852.

[18] Walters, D., and Cokljat, D., "A three-equation eddy-viscosity model for Reynolds-averaged Navier-Stokes simulations of transitional flows," *Journal of Fluids Engineering*, Vol. 130, No. 12, 2008, pp. 121–401.

[19] Menter, F., Langtry, R., Likki, S., Suzen, Y., Huang, P., and Volker, S., "A correlation-Based Transition Model Using Local Variables: Part I Model Formulation," *Turbo Expo 2004*, , No. Vol.4, 2004, pp. 1–16. doi:ASME-GT2004-53452.

[20] Silton, S., and Weinacht, P., "Effect of rifling grooves on the performance of small-caliber ammunition," *26th Army Science Conference*, 2008.

[21] Silton, S., and Howell, B., "Predicting the Dynamic Stability of Small-Caliber Ammunition," *25th International Symposium on Ballistics*, 2011.

[22] Weinacht, P., "Validation and Prediction of the Effect of Rifling Grooves on Small-Caliber Ammunition Performance," *AIAA Atmospheric Flight Mechanics Conference and Exhibit*, 2006. doi:10.2514/6.2006-6010.