19th International Symposium of Ballistics, 7–11 May 2001, Interlaken, Switzerland

AERODYNAMIC WIND-TUNNEL TEST OF A RAMJET PROJECTILE

F. Dionisio[1] and A. Stockenström[2]

[1]Defencetek, CSIR, P O Box 395, Pretoria, 0001, South Africa
[2]Dynax CC, P O Box 70336, The Willows, 0041, Pretoria, South Africa

A number of studies aimed at increasing the range of a 155 mm artillery round have led to a concept ramjet projectile designated as PRORAM [1]. Defencetek has been contracted by Somchem to design, manufacture and test such a configuration in its HSWT (High Speed Wind-tunnel) blow-down facility.

WIND-TUNNEL START-UP LOAD PROBLEMS

Preliminary calculations of the wind-tunnel start-up loads resulting from the large model plan form at the proposed Mach range (M2.2 to M3.0), led to the implementation of an unique model and balance (load measuring device) protection system. A solution had to be found such that the model could be tested at high Mach numbers without incurring any damage to the costly balance in use. Various supersonic blow-down facilities around the world employ protective plates that retract into the tunnel walls [2] shortly after the start of the blow in order to protect the model from the high start-loads (2100 N for the case in study). Limited funding prompted a cheaper and more adaptable solution to be found. The protective system, named the grounding mechanism (Fig. 1), comprises a taper lock mechanism which is driven into a matching taper on the model centre-body section by rods which are connected to a motor located in a protective housing (Fig. 2). At the start of the blow, the mechanism is locked onto the model in order to transfer the high loads directly into the sting. The taper lock is then retracted for the duration of the blow and locked again for the stop shock at the end of the test.

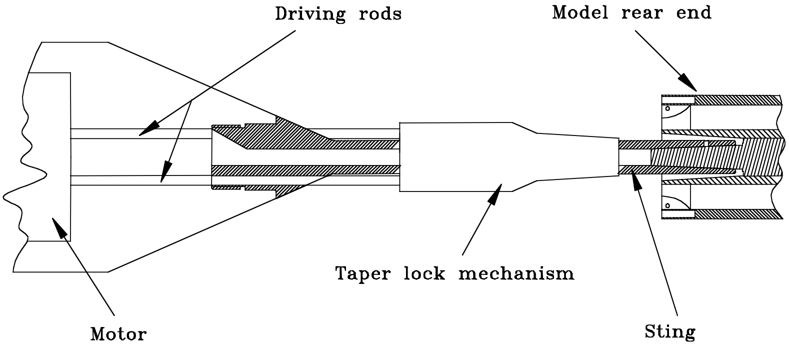

Figure 1: Schematic view of grounding mechanism.

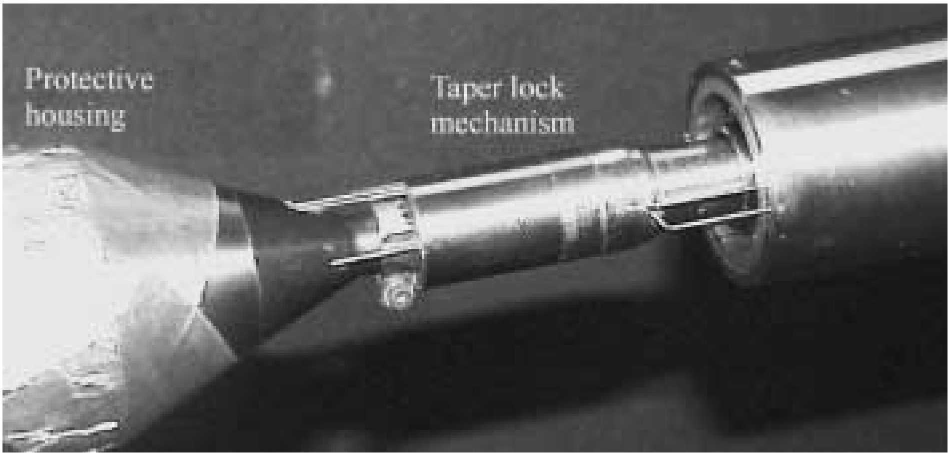

Figure 2: Grounding mechanism in wind-tunnel.

MODULAR WIND-TUNNEL MODEL

The 1/3 scale model with through flow was designed and manufactured (Fig. 3) to incorporate the grounding mechanism concept. With a diameter of 52 mm and a nominal length of 344 mm, the model facilitates the use of different cowl and cone geometries for the investigation of different inlet designs (Fig. 4). In addition, a number of outlet nozzles were designed to simulate various throat exit sizes, Figure 5.

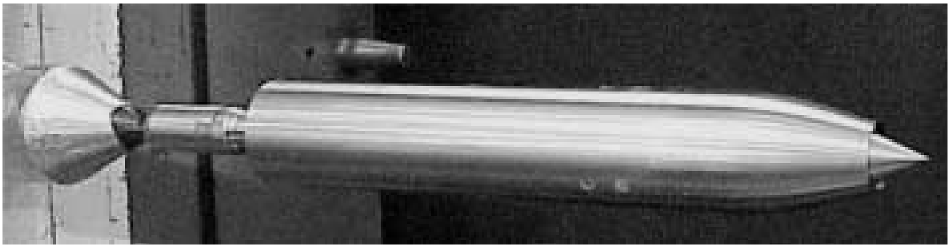

Figure 3: Program wind-tunnel model.

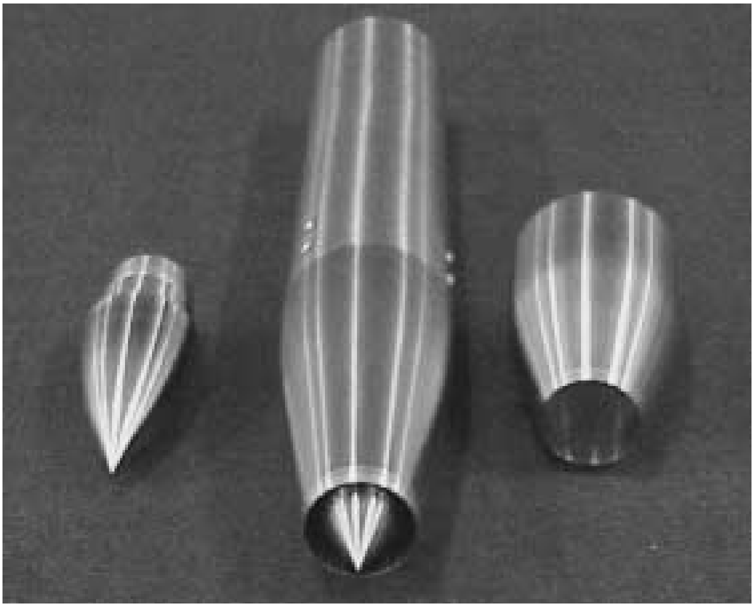

Figure 4: Cowl and cone sets.

Figure 5: Model rear end with nozzle removed.

LOAD AND PRESSURE MEASUREMENTS

Model load measurements were acquired using a six component 12 mm strain gauge internal balance. A six port rake located at the rear end of the model (Fig. 2) was utilized to characterize the flow performance of the various inlet and nozzle configurations. Fig. 6 shows a Schlieren picture of the model during a test.

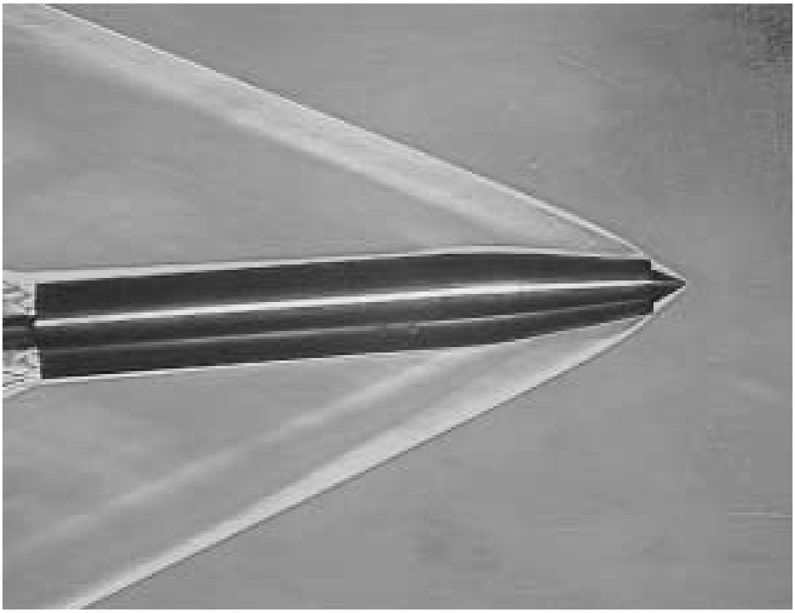

Figure 6: Test Schlieren at Mach 3.0.

DERIVATION OF THE AXIAL FORCE COEFFICIENT

The first part of the test was structured around verifying the soundness of the experiment, specifically with regards to C_A, axial force coefficient. With axial force defined as the sum of the external drag forces, it follows that the inlet and exit momentum stream thrust components need to be determined and subtracted from the measured axial force. These two quantities are both derived from measurements of the stagnation pressure upstream of the converging exit nozzle, Fig. 7. Assuming sonic conditions at the nozzle throat (which is also the exit plane), the mass flow rate, exit plane static pressure and exit plane velocity are calculated [3]. This yields the exit stream thrust. With mass flow rate known, the inlet stream thrust is simply derived from the free stream velocity.

The data presented refers to forebody drag (i.e. drag corrected for base pressure effects). The base of the model consists of two areas, inside and outside of the nozzle base internal diameter. Base pressure measurements are acquired for both areas so that the base drag contributions are accounted for separately. In order to extrapolate the wind-tunnel data to a real life projectile, an estimate of the base pressure is required. The pressures measured in the tunnel are not representative because the nozzle geometry differs from the flight geometry and the exit gas stream is at a different Mach number.

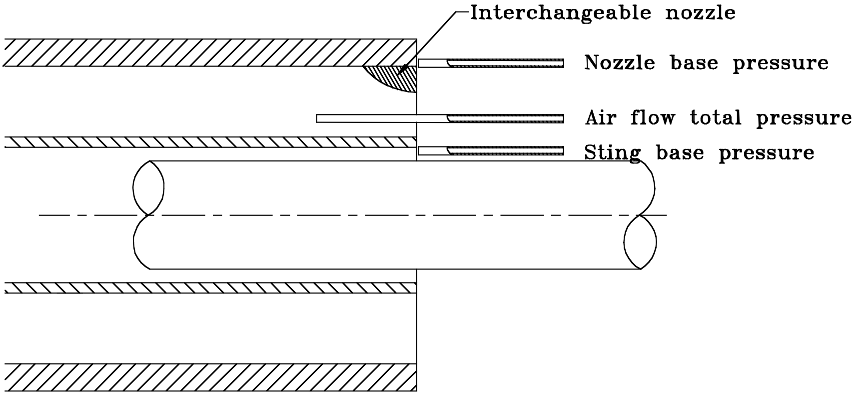

Figure 7: Schematic of pressure rake.

Tests conducted with different nozzles yielded similar results, as expected and shown in Fig. 8. The axial force components are sensitive to changes in nozzle throat diameter. A smaller throat, for instance, requires a higher stagnation pressure to yield the same mass flow rate. Obtaining the same end result with different geometries and acquired data sets confirms the inlet flow measurement and the derivation method for axial force coefficient.

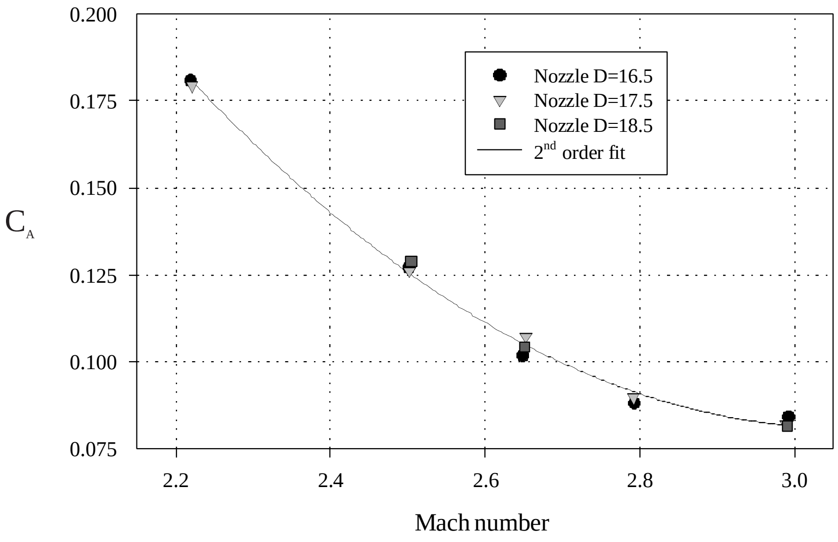

Figure 8: Confirmation of experimental method.

WIND-TUNNEL RESULTS

Different cowl and inlet configurations were tested. The practical consideration is that a blunter cowl allows space internally for better inlet geometries and more fuze and payload volume. This needs to be traded off against the predicted increase in wave drag on the cowl. The inlet design Mach number (M at which the shocks focus at the lip) determines the point below which the axial force increases sharply due to additive drag. The effect of this is simulated by employing a spacer ring to position the inlet cone slightly forward.

Fig. 9 shows the considerable drag increase due to a blunter cowl shape. At Mach 2.65, the increment amounts to 0.068. For the PRORAM concept, this huge drag increment makes the sleek cowl the optimum configuration.

The effect of inlet design Mach number is relatively smaller, but significant for the sleek cowl configuration. For the blunt cowl configuration, the small change due to lower than design Mach number is believed to be a result of the increased additive drag being offset by a lower static pressure on the cowl behind the inlet cone shock.

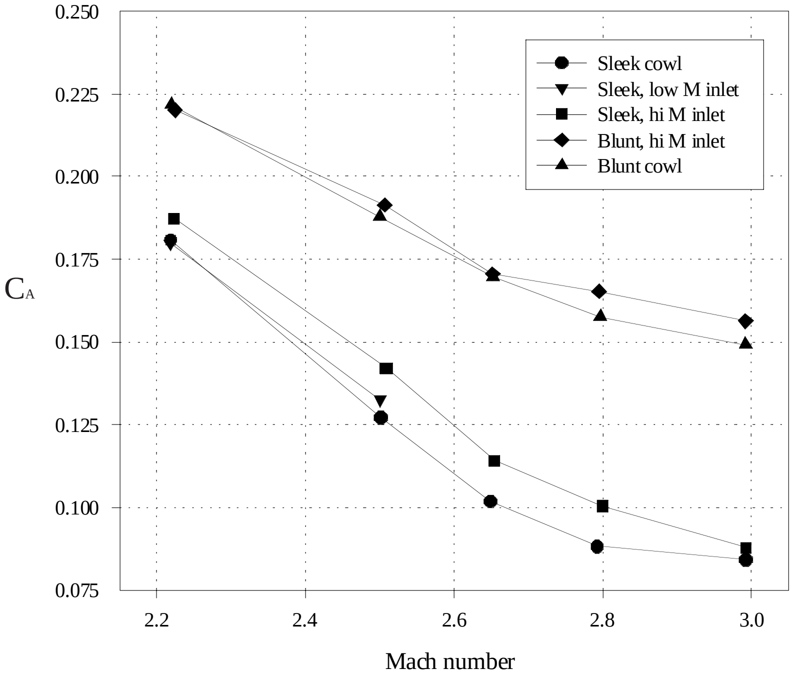

Figure 9: Axial force for various configurations.

Home
Table of Contents

The effect of the cowl configurations on stability is less pronounced. Fig. 10 shows fairly similar curves for pitching moment derivative ($C_{M\alpha}$). These aerodynamic characteristics are similar to those for blunt nosed projectiles.

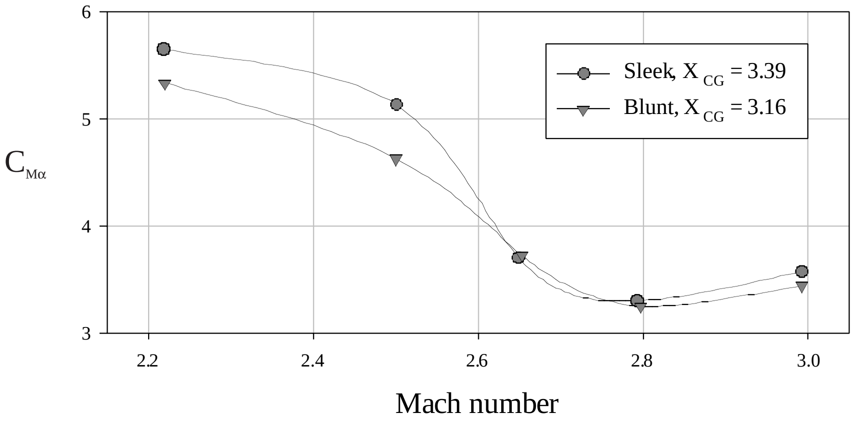

Figure 10: Stability.

The results achieved confirm the experimental soundness of the tests. The sampled data allows optimisation of the external shape and serve as a good aerodynamic database for the PRORAM project.

REFERENCES

1. J.J. du Buisson, G.F. Botha, R. Oosthuizen, “Solid Fuel Ramjet (SFRJ) Propulsion for Artillery Projectile Applications – Concept Development Overview”, *Proceedings of the 19th International Symposium on Ballistics, Interlaken, Switzerland*, May 2001
2. A. Pope, K.L. Goin, “High-Speed Wind-Tunnel Testing”, *John Wiley & Sons*, 1965
3. M.J. Zucrow, J.D. Hoffman, “Gas Dynamics Volume 1”, *John Wiley & Sons*, 1976