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A SIMPLIFIED BASE-BLEED UNIT FOR ARTILLERY PROJECTILES

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The artillery projectile range can be increased by decreasing the aerodynamic drag by means of ejecting hot gas from a base-bleed unit into the base flow of the projectile.

A new base-bleed/hollow-base construction is suggested. In this concept, a hollow chamber in the projectile base is closed at some point of the intermediate ballistic phase and subsequently, the in-captured high pressure propellant gas is leaked out through small holes.

The out-bled mass flow is estimated to last only the first few kilometers of the flight. However, the first kilometers are the most important from the point of view of extended range, and the new concept is believed to be a promising choice, especially taking into account the minimal effect on the dispersion of rounds. No fragile propellant unit is present and the technical risk is in finding out the proper valve mechanism to keep the captured gas in the chamber.

Some preliminary computations are made to estimate the potential of the new unit to extend the range. The gas leakage efficiency is assumed to be of the same order as in case of an ordinary unit. However, the high-velocity jets might provide a way to control the main flow pattern around the base region and in this way, somewhat higher drag reducing efficiency might be obtained. Some CFD computations are needed to verify this assumption, but these are outside the scope of this preliminary study.

INTRODUCTION

The artillery projectile range is typically increased by decreasing the aerodynamic drag via ejecting hot gas from the base of the projectile. In order to do that, some propellant and a burning chamber are needed attached to the base; the facility is called the base-bleed unit.

A new base-bleed/hollow–base construction is presented in this study. In this concept, the hollow chamber at the projectile base is closed at some point of the intermediate ballistic phase, and the captured high pressure is subsequently leaked out through small holes. The out-bled mass flow is estimated to last only the first few kilometers of the flight. In contrast the typical base bleed unit propellant may burn up to the trajectory apex decreasing the drag all the way up there.

However, the first kilometers are the most important from a point of view of extended range, and the new concept is believed to be a promising choice especially taking into account the minimal effect on the dispersion of rounds. No fragile propellant unit is present and the technical risk is in finding out the proper valve mechanism to keep the captured gas in the chamber.

UNIT CONCEPT

The new type base-bleed unit concept is depicted in Figure 1. The valve mechanism is to be designed in such a way that it will close at some point of the internal or intermediate phase. A pressure of 100 MPa is estimated to be captured via the mechanism.

The unit wall thickness t is estimated in this study using eq. (1) for pressure vessels [1].

$$t = \frac{kpr}{\sigma_{ult}} \tag{1}$$

The steel ultimate tensile strength (σ_{ult}) is assumed to be 1000 MPa, factor of safety (k) 1.5, pressure captured (p) 100 MPa and chamber average radius (r) 0.07 m. The wall thickness obtained is about 10 mm. Based on this computation, a chamber volume at least of 1 dm^3 seems to be possible to achieve in case of a 155 mm projectile.

Figure 1.New base-bleed unit concept. A valve mechanism will be closed by internal pressure at some point of the intermediate ballistic phase.

UNIT INTERNAL BALLISTICS

The propellant gas properties (captured into the 1 dm^3 chamber) are assumed to correspond to a temperature (*T*) of 2000 K and a gas constant (*R*) of 250 J/(kgK). The density of the gas would then be about 200 kg/m^3 based on the gas equation of state, and the resulting mass of gas is about 200 g.

The dimensionless mass flow (*I*) (out of the unit during flight) is defined according to

$$I = \frac{\dot{m}}{S_{projectilebase} V_{proj} \rho_{air}} \tag{2}$$

The projectile launch velocity used in this study is 900 m/s, air density (ρ_{air}) at launch is 1.2 kg/m^3 and the base area ($S_{projectilebase}$) of projectile is 0.015 m^2.

A high base-drag reduction factor CRED (0.6, reduction 60 %) is achieved when *I* is about 0.005 [2]. The total drag reduction would then be about 20 %.

The mass flow $\dot{m}$ out of the unit would then have to be about 75 g/s at launch (I = 0.005). The projectile velocity and air density will decrease rapidly after launch and also the mass flow needed to achieve the desired drag reduction. The estimated gas mass of 200 g is assumed to last, say, the first 4 seconds of flight. The effect of possible chemical reactions still taking place is not taken into account in this study.

EXTERNAL BALLISTICS

The nozzle area needed to achieve the required mass flow was estimated based on isentropic 1-D flow equations. The ratio of specific heat values (γ) used in this study is 1.2. The simplified gas dynamics equations were used all the way through this study for preliminary performance estimation even no kind of equilibrium exists in the unit.

The velocity at each nozzle throat (speed of sound) was determined to be about 750 m/s (V_{gas}) and static density (ρ_{gas}) about 125 kg/m^3.

The mass flow ($\dot{m} = \rho_{gas} V_{gas} A_{nozzle}$) of 75 g/s (at launch) requires a total nozzle throat area of about 1…2 mm^2 depending on the discharges of the nozzles (viscous effects).

The needed exhaust area may be divided for multiple nozzles through the base wall. The gas bleeding efficiency (drag reduction achieved) is assumed to be of the same order as in case of an ordinary unit. However, the high velocity jets might be used to control the main flow around the base region, and in this way even somewhat higher drag reduction is hoped to be obtained (see Figure 2).

In case the unit would loose efficiency because of the high-speed jets, a construction imitating the ordinary base-bleed unit is to be used instead (see Figure 3).

Figure 2. Properly located/pointed high-velocity jets might be used to control the main flow around the base region and in this way somewhat higher drag reduction might be obtained.

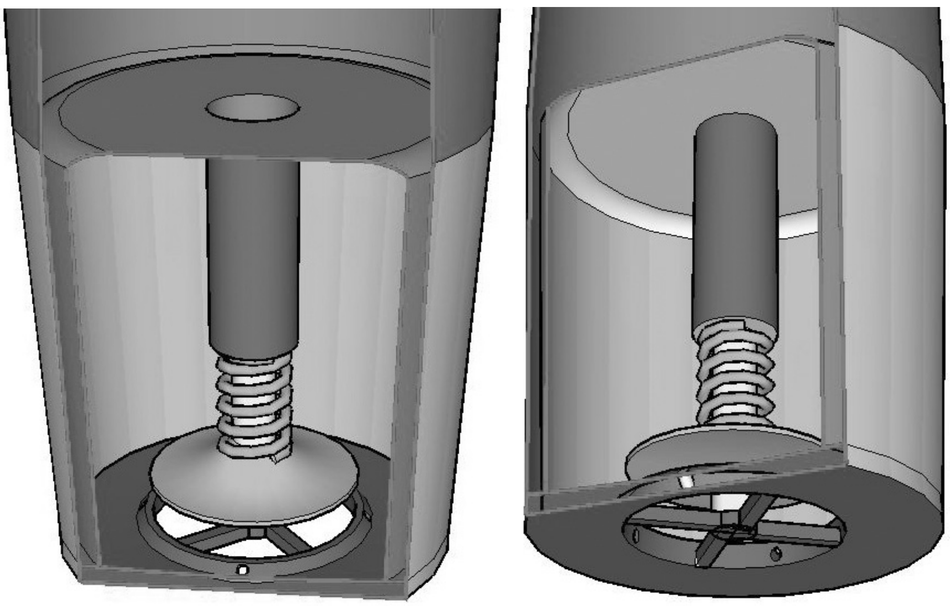

Figure 3. Internal pressure can be bled to a base center cavity through small bleeding holes.

Some trajectories were computed for a 155 mm projectile (launch mass 43.2 kg). The projectile launch velocity (V_{launch}) used in this study is 900 m/s and elevation angle 50 degrees. The trajectories were computed using a normal value for the zero-yaw drag coefficient (no unit) and also reducing the drag 20 % during the first 4 seconds of flight (with unit).

The trajectories and drag coefficients used are depicted in Figures 4 and 5. The range was extended by about 5 % when the new-type unit effect (drag reduction) was included in the computations.

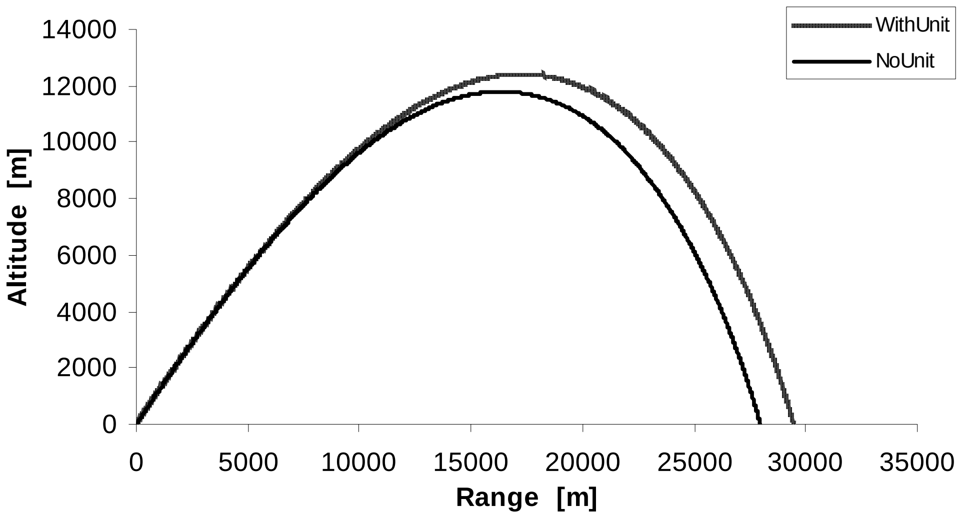

Figure 4. 155 mm projectile trajectories with and without unit-caused drag reduction.

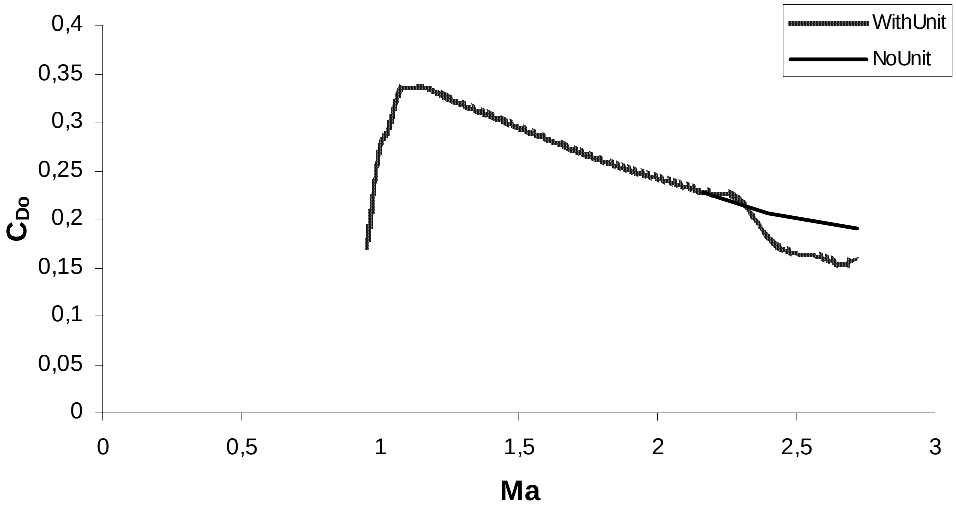

Figure 5. 155 mm projectile zero-yaw drag coefficient during the flight initiating at Ma=2.7 with and without unit-caused drag reduction.

CONCLUSIONS

Some preliminary computations were made to estimate the capability of a new base-bleed unit to extend projectile range.

The new-type unit extended the 155 mm projectile range by about 5 % with quite conservative assumptions.

The high-velocity exhaust jets might be used to control the main flow around the base region and in this way, somewhat higher drag reduction might be obtained. Some CFD computations are needed to verify this assumption and these are outside the scope of this preliminary study.

The effects of gas chemical reactions possibly still taking place during the bleeding phase were not taken into account in the study. These also might have a drag reduction gaining effect.

[1] E. L. Fleeman, Tactical Missile Design, *AIAA Education series* (2001).
[2] E-N. Gunners, K. Andersson, R. Hellgren, Base-Bleed Systems for Gun Projectiles, *AIAA Progress in astronautics and aeronautics*, Vol. 109 (1987).