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Ramjet Propulsion for Projectiles - An Overview of World-Wide Achievements and Future Opportunities

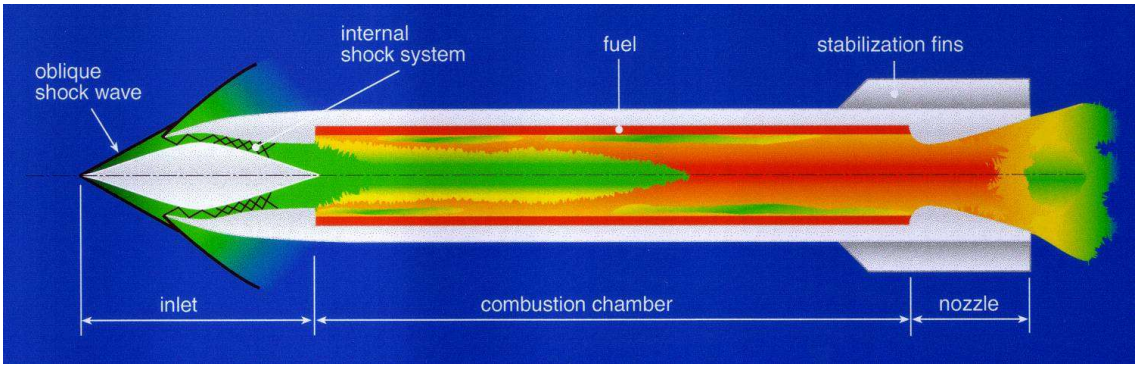
Ronald Veraar[1], Kurt Andersson[2] and Roelof Oosthuizen[3]

[1] TNO Defence, Safety and Security, The Netherlands
[2] Retired from FOI, Swedish Defence Research Agency/FHS, The Swedish National Defence College (SNDC), Sweden
[3] Rheinmetall Denel Munition, South-Africa

Extended abstract

A ramjet engine is a form of an airbreathing jet engine which uses its forward motion to compress the incoming air. In contrast to a normal jet engine, the ramjet engine does not have a rotating compressor and is not able to generate thrust at zero speed. Soon after the invention of the ramjet engine cycle in 1913, people started to look at applying this engine cycle to gun-launched projectiles in order to increase the range. Since then, numerous studies have been performed on ramjet projectiles. Due to the absence of a fuel feed system and associated complexity, the Solid Fuel Ramjet (SFRJ) received significant attention the past few decades. Attempts to progress the SFRJ technology were undertaken, amongst others, in the United States of America, Israel, Sweden, South Africa, South Korea, and the Netherlands.

The SFRJ propulsion system combines high propulsive performance with a very low degree of mechanical complexity. As such, it is a very attractive propulsion system for gun-launched projectiles. The propulsive force generated by this propulsion system can serve to reduce time-to-target and/or increase the kinetic energy on the target or to increase the range of projectiles. The functioning of an SFRJ projectile is, however, dictated by complex physical phenomena with strong interactions. A successful design of such a projectile thus requires detailed knowledge of the performance at subsystem level as well as at the projectile's system level.



Schematic cross sectional view of a generic fin stabilized solid fuel ramjet projectile

The present paper intends to give an overview of world-wide achievements in the field of ramjet propelled gun-launched projectiles, from the early activities in the beginning of the previous century up to the most recent activities related to application of SFRJ technology to extend the range of guided artillery ammunition beyond 100 km. This will be done based on an extensive review of open publications on the subject of SFRJ. More detailed descriptions will be given of, amongst others, the following SFRJ technology development and demonstration programs executed in Sweden, South Africa, and the Netherlands:

- A co-operative study programme on SFRJ propelled projectiles performed by FOI, the Swedish Defence Research Agency (formerly FOA), and TNO aiming at a flight demonstration of this technology. Technology development work on aerodynamics, combustor and nozzle performance, projectile performance prediction, mechanical design, and the gun system enabled the design of a generic fin-stabilized SFRJ projectile. Flight tests performed demonstrated that the projectile was capable of generating a thrust equal to its aerodynamic drag, resulting in a constant flight velocity capability.
- A technology development effort on a 155 mm ramjet assisted spin-stabilized artillery shell performed by Rheinmetall Denel Munition (formerly Somchem, Division of Denel) in South Africa, aiming to demonstrate a range of at least 70 km. As part of this effort, wind tunnel tests on the intake have been performed as well as initial gun firings of integrated designs of a ramjet artillery shell.
- A technology demonstration programme performed by TNO in co-operation with Rheinmetall Waffe Munition Schweiz (formerly Oerlikon Contraves Pyrotec) on the application of SFRJ propulsion technology for medium calibre spin-stabilized air defence projectiles. Elements of this activity were verification of the fuel mechanical properties and the on-ground verification of the propulsion system performance in a free jet test facility. This program resulted in the world's first successful Mach 4+ flight demonstration of the SFRJ technology integrated into a projectile fired from a standard gun.
- Technology development work performed by TNO to establish the flameholding limits of a central dump SFRJ combustor at operating conditions which are representative for large calibre artillery ammunition.

Based on the status of the SFRJ projectile technology as summarised in the paper, an outlook will be given on the potential of this technology for various future applications. Performance potential and considerations for applying this technology to various applications ranging from medium-calibre direct fire to large-calibre indirect fire will be presented.