A supersonic combustion ram cannon (1) includes a conical projectile (8) with a flat base (9) which produces a subsonic wake (12) as it flies through a barrel (2). The projectile is configured to avoid a normal shock, relying instead on supersonic compression, combustion and gas expansion. The supersonic combustion of a fuel-oxidizer mixture around the tail of the subsonic wake, pressurizes the wake and drives the projectile forward. By utilizing wake stabilized supersonic combustion, the compression and combustion pressures can be matched to the limiting barrel working pressure, thereby providing for optimum thrust and maximum projectile acceleration.
PRIOR ART

FIG. 2b

THERMALLY CHOKED RAM CANNON

PRIOR ART

FIG. 2c

SUPERSONIC COMBUSTION RAM CANNON

PRIOR ART

FIG. 2d

OBLIQUE DETONATION WAVE RAM CANNON
WAKE STABILIZED SUPersonic COMBustion RAM CANNON

TECHNICAL FIELD

This invention relates to ram cannons and more particularly to a supersonic combustion ram cannon which utilizes a subsonic projectile wake to stabilize the supersonic combustion process.

BACKGROUND ART

The ramjet principal of propulsion is well known in the art. During the flight of a ramjet powered vehicle, high velocity air enters a diffuser in the front of a ramjet engine which is shaped to slow the flowing air, thereby inducing compression of the airstream. The compression of the airstream generates a normal shock wave which slows the flowing air to subsonic velocities. As the air enters a combustion chamber, fuel is continuously injected into the combustion chamber and ignited, producing hot combustion gases. Forward vehicle thrust is provided by the ejection of the hot combustion gases through a discharge nozzle at a velocity greater than the flight speed. Since a ramjet relies on high air flow velocity through a diffuser rather than mechanical apparatus to achieve compression, ramjets require minimum flight speeds of approximately Mach 1-3 for efficient operation. Generally, chemical rocket motors or turbine type engines must be used to propel a ramjet-powered vehicle to such minimal flight speeds before ramjet propulsion is initiated.

Adapting the ramjet principal of propulsion to gun-fired projectiles significantly increases the range of artillery and the destructive potential of projectile discharging weapons. Conventional explosive propulsion generally accelerates a projectile to supersonic speeds between Mach 1.5-4.0. Ramjet propulsion extends the flight of a projectile by further accelerating such a projectile to hypersonic speeds (Mach 5.0 and above). Prior art weapons, utilizing the ramjet principle to boost projectile speed, have included various modified projectiles incorporating ramjet engines which initiate further acceleration after discharge from a conventional gun barrel. Such projectiles include an outer casing, an inner compression and combustion chamber, an integral fuel supply, and a discharge nozzle. U.S. Pat. No. 4,428,293 to Botwin et al discloses such a projectile which also includes variable thrust control of the projectile after discharge from a gun.

A ram cannon uses the ramjet principle to promote projectile acceleration before discharge from a gun barrel. By firing a projectile through a barrel section containing a fuel-oxidizer mixture, the projectile and barrel, in effect, become a ramjet engine with the barrel effectively forming the outer engine casing and the spacing between the projectile and barrel wall defining the compression and combustion chambers. In a subsonic combustion ram cannon (see FIG. 2), a discharge nozzle is included which is defined by the annular spacing between the projectile tail and the barrel wall. As the projectile passes through the barrel, the premixed fuel-oxidizer mixture is compressed and ignited, generating hot combustion gases which expand rearwardly through the discharge nozzle, imparting forward thrust to the projectile. A particular problem with subsonic combustion ram cannons is that such ramjet propulsion of a projectile within a gun barrel generates a rapid pressure build up during the projectile acceleration. A normal shock wave slows the flowing gas to subsonic velocities prior to combustion and induces a high pressure gradient directed to the barrel wall. It is at this point in the ramjet cycle that the peak pressure is encountered. Since the ram cannon design is limited by the barrel working pressure, a supersonic combustion ram cannon must be designed for the shock pressure. Consequently, the maximum muzzle velocity of the projectile is limited by the pressure rating of the barrel relative to the high pressure spike that occurs at the point of normal shock.

Another problem with subsonic combustion ram cannons involves the possibility of propagating a detonation wave ahead of the moving projectile into the unburned fuel-oxidizer mixture, resulting in a preignition of the fuel-oxidizer mixture, halting acceleration of the projectile. Several alternatives have been proposed for alleviating this problem. Utilizing either a smaller diameter projectile or an oversized bore would increase the spacing between the barrel wall and projectile body, thereby decreasing the amount of fuel-oxidizer compression and moderating the normal shock pressure. However, such a loss in propulsion efficiency would also limit the projectile acceleration, thereby requiring a longer barrel to achieve a hypersonic muzzle velocity. Another proposed solution involves increasing the barrel working pressure by such methods as increasing barrel strength through increased wall thickness. However, while some weapons could incorporate such strengthened barrels, the costs and weights involved would be prohibitive.

Another alternative, disclosed in commonly assigned U.S. patent application Ser. No. 857,687 to Titus, titled "Ram Cannon Barrel", filed Apr. 31, 1986, involves the use of an outwardly flared barrel bore which provides added bore volume to offset the pressure increases. While useful in moderating the pressure buildup within the barrel, a major structural modification of the cannon barrel is required, and the maximum projectile acceleration is still structurally limited.

A variation of the subsonic combustion ram cannon utilizes a thermally choked combustion cycle (see FIG. 26). In this cycle, the combustion takes place behind the projectile in the full barrel bore area. The combustion process therefore reaccelerates the gas flow to supersonic speed in the aft barrel area, thereby accelerating the projectile. While providing good performance at low speeds, the thrust drops off dramatically when the projectile approaches the detonation wave velocity of the propellant fuel-oxidizer mixture.

Utilizing supersonic combustion (see FIG. 2c) in a ram cannon has been investigated as a method of avoiding a normal shock and the concomitant high pressure peak. However, such supersonic combustion ram cannons include a tail section which confines the combustion area, leading to the build up of high pressure gradients in the combustion zone. Eventually, at high velocity, the supersonic combustion zone will narrow until an oblique detonation wave forms (see FIG. 2d), providing a very narrow reaction zone, similar to the normal shock wave. Since this pressure cannot exceed the barrel limiting pressure, the high pressures generated with the oblique detonation wave effectively limits the potential thrust.

Consequently, the search continues for a ram cannon capable of attaining high muzzle velocities with opti-
The document appears to be a page from a technical or scientific publication discussing the properties of a ram cannon and its operation, focusing on the effects of supersonic combustion and the efficiency of projectile acceleration. The text is likely discussing the mechanics and design considerations of the cannon, including the combustion processes within the barrel and the impact on propulsion efficiency.
stream barrel pressure, is plotted along with the various ram compression ratios for various throat areas. Generally, throat area ratios of from 0.05-0.50 will provide acceptable results. However, from the graph, it can be seen that a preferred throat area ratio of 0.25 (i.e. a contraction ratio of 4 to 1) provides a ram compression ratio comparable to the combustion pressure ratio. Thus, no strong expansion or compression waves would be generated at the projectile base during compression and combustion. Therefore, the maximum pressure in the barrel would be the combustion pressure which could be made comparable to the barrel limiting pressure, thereby maximizing projectile thrust and acceleration.

Referring to FIG. 5, the thrust parameter for the wake stabilized supersonic combustion ram cannon is shown for four throat area ratios, normalized by the reference force $P_{max}/P_0$, where $P_{max}$ is a structurally limiting factor, such as the barrel working pressure. Also plotted are the values for two other types of ram cannons, the thermally choked ram cannon (line A) and the conventional supersonic combustion ram cannon (line D). From the graph, it is seen that the wake stabilized supersonic combustion ram cannon is superior to either of these other cycles in delivering higher thrust over a wide range of projectile velocities.

A significant advantage derived from utilizing a conical projectile in a ram cannon is the aerodynamic stability of the projectile geometry. With projectiles traveling at hypersonic speeds, flight stability is an important factor in determining the ultimate practicality of a ram cannon. The velocities are such that spin stabilization could not be used. However, a conical projectile, properly balanced to locate the center of gravity at the optimum location and utilizing a subsonic wake to pressurize the flat base, could provide stability at these high velocities.

The supersonic combustion ram cannon utilizing a wake stabilized configuration eliminates many of the problems which exist with other ram cannon designs. Utilizing supersonic combustion as the operating mode reduces the likelihood of detonating the fuel-oxidizer mixture when projectile velocities are below the detonation wave velocity of the mixture. By utilizing the subsonic wake to stabilize the combustion process, the base pressure generated is relatively insensitive to the rate of heat release in the supersonic stream surrounding the wake and the base pressure is therefore comparable to the maximum pressure in the thrust cycle, thus allowing matching of the propelling pressure to the barrel working pressure, thereby providing maximum projectile acceleration. In addition, this configuration reduces the likelihood of forming an oblique detonation wave.

It will be understood by those skilled in the art that this invention is applicable to any device incorporating ramjet propulsion of a projectile within a barrel. While the preferred embodiment of the present invention is described in relation to a conically shaped projectile hyperaccelerated in a fuel-oxidizer containing barrel, it will be understood by those skilled in the art that modifications in the bore taper, barrel type, sealing means, attaching means, bore surfacing, fuel-oxidizer mixture, projectile contour, throat area ratio or ignition source can be made without varying from the present invention.

Having thus described the invention, what is claimed is:

1. A wake stabilized supersonic combustion ram cannon in combination with a projectile, said cannon being of the type adapted for firing said projectile throughout in accordance with ramjet principles, said cannon including a barrel having a bore extending therethrough, a breech end and a muzzle end, and means for sealing said barrel ends, wherein said projectile traveling through said barrel bore compresses a fuel-oxidizer mixture contained therein, gas generated by the ignition and combustion of said compressed mixture accelerating said projectile through said barrel, said projectile comprising an essentially conically shaped body with an essentially flat base, the projectile and barrel configured to provide supersonic compression and combustion of said fuel-oxidizer mixture, said conically shaped body producing a convergent subsonic wake as it travels through said barrel, said wake stabilizing the supersonic combustion process by spreading the combustion gases over the diverging region surrounding the wake, moderating pressures within the barrel, such that the compression and combustion pressures are essentially matchable to the barrel limiting pressure, thereby maximizing projectile acceleration.

2. The ram cannon of claim 1 wherein said projectile and barrel are configured to provide supersonic compression with an aerodynamic contraction ratio of from 0.05-0.50.

3. The ram cannon of claim 2 wherein said projectile are configured to provide supersonic compression with an aerodynamic contraction ratio of 0.25.

4. The ram cannon of claim 1 wherein said fuel-oxidizer mixture comprises a mixture of a gaseous fuel and an oxidizer.

5. The ram cannon of claim 1 wherein said projectile has an optimally balanced center of gravity to provide stabilized flight at supersonic speeds.

6. A projectile for use in a ram cannon of the type adapted for firing a projectile therethrough in accordance with ramjet principles, said cannon including a barrel having a bore extending therethrough, a breech end and a muzzle end, and means for sealing said barrel ends, wherein said projectile traveling through said barrel compresses a fuel-oxidizer mixer contained therein, gas generated by the combustion of said compressed mixture accelerating said projectile through said barrel, said projectile comprising:

   an essentially conically shaped body with an essentially flat base, configured relative to said barrel for providing supersonic compression and combustion of said fuel-oxidizer mixture, said conically shaped body producing a convergent subsonic wake as it travels through said barrel, said wake stabilizing the supersonic combustion process by spreading the combustion gases over the diverging region surrounding the wake, moderating pressures within the barrel, such that the compression and combustion pressures are essentially matchable to the barrel limiting pressure, thereby maximizing projectile acceleration.

7. The projectile of claim 6 configured, relative to said barrel, for providing supersonic compression, with an aerodynamic contraction ratio of from 0.05-0.50.

8. The projectile of claim 7 configured, relative to said barrel, for providing supersonic compression with an aerodynamic contraction ratio of 0.25.

9. The projectile of claim 6 having an optimally balanced center of gravity to provide stabilized flight at supersonic speeds.

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