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Title: Solid Propellant Grain for Improved Ballistic Performance of Guns.

Classification: Class Subclass

NOTICE

The Government owned invention described herein is available for licensing. Inquiries and requests for license information should be addressed to:

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Title of Invention: Solid Propellant Grain For Improved Ballistic Performance Of Guns
Serial Number: 043,767
Filing Date: 30 MAY 79
Docket Number: BRL 3-77

GOVERNMENTAL INTEREST

The invention described herein may be manufactured, used and licensed by or for the Government for Governmental purposes without the payment to me of any royalty thereon.

BACKGROUND OF THE INVENTION

This invention has to do with propellants for use in gun systems. More specifically, this invention has to do with a novel shape for propellant grains which enhances the burning charateristics of the propellant material such as to achieve higher muzzle velocity of a projectile without increasing the maximum experienced pressure within the barrel of the gun in use.

As is well kncwn,the purpose of propellant materials in a gun system is to provide a source of energy for accelerating a projectile within the bore of a gun so that a desired muzzle velocity for the projectile is achieved. The projectile, initially at rest, is accelerated by force resulting from the generation of high pressure gaseous products in response to the ignition and burning of the propellant material.

As is also generally known, the burning of solid propellants ordinarily utilized in gun systems is initiated by some action, e.g. the release of a firing pin, which generates a small amount of hot gas in proximity to the propellant thus causing the propellant material to ignite and the burn process to commence.

Once ignition is achieved, it is desirable to have the propellant burn in a controlled manner from the surface of the propellant grains inwardly. Where the burn is essentially uniform over the whole propellant grain,the surface receeds parallel to itself, gas is generated evenly and the resulting pressure accelerates the projectile down the bore.

As is also well known in the arts, the ultimate or muzzle velocity of a projectile thus accelerated is related to and dependent upon the pressure-time history after ignition. Thus maximum pressure achieved during the burn as well as the magnitude of the sustained pressure after maximum has been reached are the primary factors in being able to achieve desired muzzle velocity within the limitations of acceptable gun structure.

For purposes of understanding fully the present invention, it is considered to be worthwhile to review the relationships of various factors which have an effect on muzzle velocity in any particular gun system.

The differential equations governing the acceleration of a projectile down the bore of a gun to a desired velocity are Newton's Law and the Propellant Burning Law respectively:

(1) $$PA-f = m \frac{d^2x}{dt^2}$$ (Newton's Law)

(2) $$\frac{dC}{dt} = S \frac{dr}{dt}$$ (Propellant Burning Law)

where:

P	=	Pressure acting on base of projectile
A	=	bore area
f	=	engraving and frictional force
m	=	mass of projectile
x	=	projectile travel
C	=	mass of propellant burned
	=	density of solid propellant
S	=	surface area of solid propellant
$\frac{dr}{dt}$	=	propellant rate of surface regression
t	=	time

The launch velocity, from equation (1) Newton's Law is:

$$\frac{dx}{dt} = v = \frac{1}{m} \int_0^{t_m} (PA-f)\,dt$$

where:

v = velocity

t_m = time to travel to forward end or muzzle, of gun.

Because the friction factor in equation (1) i.e. the equation for Newton's law, is a small constant, it is clear that muzzle velocity is essentially proportional to the integral of the pressure-time history for a projectile starting from rest. Clearly, therefore, muzzle velocity can be increased by increasing the maximum pressure. However, as is discussed below, increasing maximum pressure is not an acceptable approach in many instances because of inherent limitation in presently known gun structures as well as because of the resultant fatigue stresses which shorten gun life. Further, increased maximum pressures are known to cause damage to projectiles some time with catastrophic failure of the weapon. Thus, improvement of muzzle velocity by increasing the maximum pressure during acceleration is not the most desirable approach to the problem.

Considering therefore the Propellant Burning Law, see equation (2) it can be seen that this law relates to the rate of gas evolution of the burning propellant material. The pressure time history generated thereby is the result of comparing the rate of pressure generation as a result of propellant burn with the increase in the volume of the gun chamber resulting from projectile displacement. As the propellant is initially ignited and gases are being generated, the projectile is either at rest or moving relatively slowly. Thus, gases are being generated faster than the volume of the chamber is increasing. Clearly as a result of this, the pressure experienced increases.

As the projectile accelerates down the gun bore, the volume of the chamber increases at a rate which ultimately surpasses the rate of gas generation by the burning of the propellant material. The transition corresponds to the point of maximum pressure in the chamber. Thereafter the pressure decreases as the projectile continues to accelerate thus increasing the volume of the gun chamber at a rate faster than the increase in volume of gases being generated by the propellant burn.

It has been recognized by those skilled in these arts that the rate of burn of propellant material i.e. the burn characteristics of the grain, is a function not only of the physical and chemical characteristics of the material itself but also of the shape of the grain. Known grain designs are ordinarily cylindrical elements having a single perforation therethrough or seven perforations therethrough. It has been found that grain designs having these characteristics are limited in their capability for extending of a relatively high degree of chamber pressure after the maximum pressure has been achieved. Thus, increases in muzzle velocities have been required to be achieved by increasing the maximum pressure in the gun system. However, as will be recognized by those skilled in these arts, such increases in maximum pressure are extremely expensive and result in difficult operational problems because of the requirement for increased structural capabilities of the cannon, rolling stock, support stock, and the like.

Prior attempts to achieve a higher sustained pressure subsequent to the achievement of maximum pressure have not been successful nor, for economic reasons, has it been found acceptable to resort to more esoteric propellant materials.

Typical prior art approaches may be seen by way of example in U.S. Patent No. 4,094,248; U.S. Patent 3,429,624; British Patent No. 7178 and French Patent No. 1,595,508.

In U.S. Patent No. 4,094,248 there is described a hexoganol grain with 7 internal perforations centered on the vertices of equilateral triangles, with each grain having external longitudinal grooves. This geometry does not provide for progressive burning and performance characteristics. Further, there exists gaps between the faces of adjacent propellant grains which would permit burning to take place on the face as well as the external grooves such that the actual performance of the grain design as disclosed in the patent will be similar to that of the 7 perforation cylindrical grains which are the standard U.S. gun propellant geometry.

U.S. Patent No. 3,429,264 described a solid stick propellant with a grooved hexoganol-like periphery which can be used in place of tubular propellant in rockets. There is no provision for perforations. Further, the patent teaches degressive burning, i.e. rapid initial burning and slower burning in final stages. This concept is diametrically opposite to that concept disclosed in the present application which provides for progressive burning which is essential to improved gun performance.

French Patent No. 1,595,508 describes a block of propellant formed by bonding individual propellant grains together in a matrix. The progressive burning achieved pursuant to this approach is the result of burning on the external surfaces as being inhibited by the bonding agent.

British Patent No. 7178 describes perforated propellants, perforations of which are of a shape other than cylindrical. Further, in order to maintain the equal distance, the British Patent teaches the use of grooves on the periphery to maintain the same web throughout the grain.

BRIEF STATEMENT OF THE INVENTION

It is an object of the present invention, therefore, to provide a solid propellant grain for improved ballistic performance of guns which permits achievement of increased muzzle velocities of projectiles without requiring increased maximum pressure.

Another object of the present invention is to provide a solid propellant grain for improved ballistic performance of guns wherein increased muzzle velocities of projectiles can be achieved without the necessity for increasing the structural capability of the weapon.

Yet another object of the present invention is to provide a solid propellant grain for improved ballistic performance in guns without the need for great capital investment in terms of manufacturing facilities and techniques i.e. to the use of presently known manufacturing technology.

It is still a further object of the present invention to provide a solid propellant grain for improved ballistic performance of guns wherein the grain achieves progressive burning i.e. improved burn area as the propellant material is burned whereby to achieve increased gas generation subsequent to the achievement of maximum gas pressure within the gun chamber.

These objects and others not enumerated are achieved by a solid grain propellant according to the present invention, one embodiment of which may include a propellant grain of generally cylindrical shape having a plurality of longitudinal substantially parallel perforations extending therethrough, the cross-sectional locations of said perforations being such that the interstitial distances between adjacent perforations is substantially equal and substantially equals the extrastitial distances between the perimetric perforations and the outer surface of the grain wall.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be had from the following detailed description thereof, particularly when read in the light of the accompanying drawings wherein:

FIGURE 1 is a cross-sectional view of an embodiment of propellant grain structured in accordance with the present invention;

FIGURE 2 is a longitudinal cross-sectional view of the solid propellant grain of FIGURE 1;

FIGURE 3 is a cross-sectional view of packaging of the solid propellant grains of the present invention providing for low bulk loading densities;

FIGURE 4 is a cross-sectional view of the packaging of solid propellant grains according to the invention wherein high bulk loading densities are required; and

FIGURE 5 is a graph showing relative chamber pressure versus projectile travel along the bore of a gun comparing known solid propellant performance with the performance of a solid propellant grain charge structured in accordance with the present invention.

DETAILED DESCRIPTION

As noted above this invention relates to a solid propellant grain structure for improved ballistic performance.

Referring therefore to the drawings and in particular FIGS. 1 and 2, there are shown cross-sectional views of a solid propellant grain structured in accordance with the present invention.

Referring particularly to FIGURE 1, it can be seen that the grain, designated generally by the reference numberal 10, is generally hexagonal in cross-section having six flat outer surfaces 12 joined by rounded longitudinal edges 14.

Extending longitudinally through grain 10 are a plurality of parallel throughbores 16. The positioning of throughbores 16 is critical and thus there is shown on FIGURE 1 the dimensional relationship of the respective throughbores.

The throughbores may be designated generally as internal throughbores and perimetric throughbores. The perimetric throughbores or perforations are those throughbores which are adjacent on one side the the peripheral surface of grain 10. The internal throughbores or perforations are the remaining throughbores which are within the hexagonal design of throughbores or perforations defined by the perimetric perforations.

Each of the internal throughbores or perforations is equally distant from each of the immediately surrounding throughbores or perforations. Thus, there is defined between adjacent throughbores along a line which connects their axes a wall having a thickness W_i as shown on the drawing. Thus the distance between the centers of adjacent throughbores or perforations is $W_i + d$ where d is the diameter of the through bore.

With respect to the location perimetric perforations from the outer surface of the grain, each throughbores or perforation is disposed such that the thickness of grain material between the throughbores and the surface of the grain, measured along a line perpendicular to the surface of the grain and passing through the axial center of the throughbore, dimension W_o as shown in FIGURE 1 is equal to W_i, i.e. the thickness of grain material between adjacent internal throughbores.

With respect to those throughbores which are immediately adjacent the edges 14 of the external surface of the grain, the wall thickness is maintained at the W_o dimension by rounding the edge 14 utilizing a radius arc which is equal to one-half the diameter of the perforation plus the dimension W_o.

An optimum grain structure in accordance with the invention has been found to include seven perforations along the line connecting opposite edges 14. So structured the total number of perforations provided in the grain is 37.

The chemical composition of the propellant utilized in the manufacture of grain 10 may be chosen from any one of the numerous United States Service Propellants generally known in the art. These propellants include the ones having the generally accepted designations M1, M2, M5, M6, M8, M9, M10, M15, M17, M26, M30 and M31. Further, over and above the foregoing propellants, it will be recognized by those skilled in these arts that any propellant, the characteristics of which conform to the Burning Law equation as stated above, may be utilized.

The length of the grain 10 may be varied as desired based upon the particular application with respect to which the grain is to be used. Thus, when high bulk loading densities are required, the ratio of the length of the grain to the cross-sectional distance between the edges of the grain may be inthe range of 3 to 1, or less. For low bulk loading densities the same ratio should be greater than 3 to 1.

With respect to to the packaging of the grains in use, the grains may be either packaged randomly as shown in FIGURE 3, or in the event the ratio of length to diameter exceeds 10, the propellant grains will appear as sticks and may be coaxially oriented in packing in the manner shown in FIGURE 4.

The selection of the particular packing mode, however, is within the skill of those having ordinary skill in these arts and is not a necessary consideration with respect to the practice of the present invention.

As noted at the outset of the present disclosure a propellant charge comprising solid propellant grains structured in accordance with the present invention provides improved ballistic performance. Referring therefore to FIGURE 5, there is shown in graphic form a comparison of the chamber pressure for a conventional propelling charge with the chamber pressure of a charge incorporating solid propellant grains structured in accordance with the invention. It can be seen that the maximum pressure achieved is substantially identical whereas the pressure for propelling the projectile is higher along substantially the entire length of travel of the projectile within the chamber for all points subsequent to the point of travel beyond that where maximum pressure occurs.

The net effect of this phenomenon is that the muzzle velocity of the projectile being propelled by solid propellant structured in accordance with the present invention is greater than that experienced by prior art charge structures. This of course is an improved operation.

For purposes of improved economy, it should be recognized that a solid propellant grain charge may be utilized to provide a muzzle velocity equal to that of the standard perforation charge but which requires a less maximum pressure. This represented in FIGURE 5 by the curve shown with the broken line.

Thus, it can be seen that through the desired choice of either comparative muzzle velocity or comparative maximum pressure, benefits may be achieved by utilization of a solid propellant grain structure according to the invention.

It will be recognized by those skilled in these arts that the solid propellant grain structure according to the invention may be manufactured in accordance with techniques generally known in the field e.g. casting and the like.

It will also be recognized by those skilled in these arts that the mechanism for achieving the improved characteristics of the ballistics charge is achieved through providing optimum surface burn area which burn surface increases relatively over the life of the burn thus contributing to the maintenance of the relatively increased pressure rate subsequent to the achievement of maximum pressure.

ABSTRACT OF THE DISCLOSURE

A propellant grain for improved ballistic performance of guns, the grain comprising a cylinder of generally hexagonal cross-section being provided with a plurality of perforations, preferably 37, passing therethrough. The perforations are disposed such that the interstitial distance between adjacent perforations is substantially equal and the extrastitial distance between peripheral perforations and the surface of the outer wall is substantially equal to the aforesaid interstitial distance. The novel shape of the solid propellant grain improves ignition and burning characteristics such that higher average pressures are maintained during projectile acceleration without increasing the maximum pressure within the gun barrel.

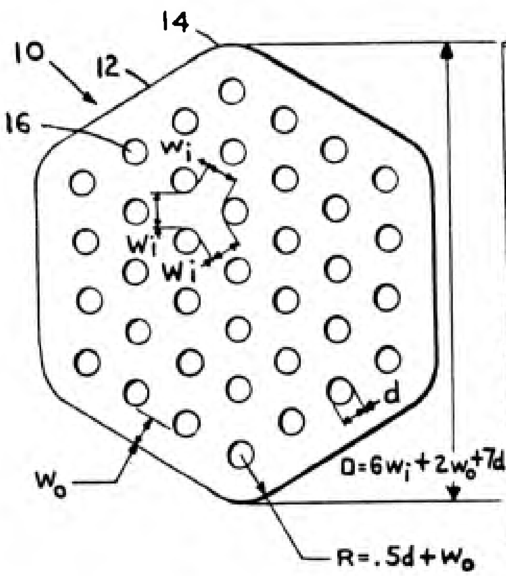


FIG. 1

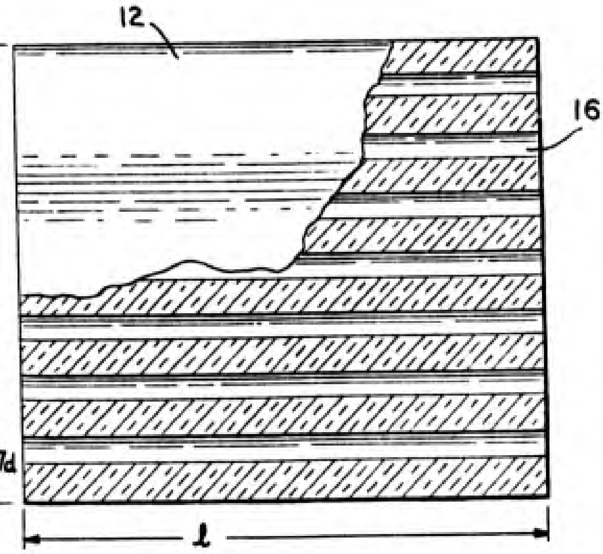


FIG. 2

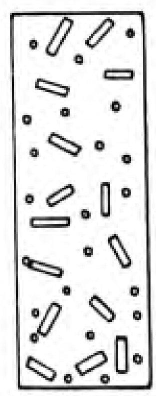


FIG. 3

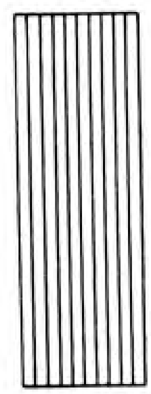
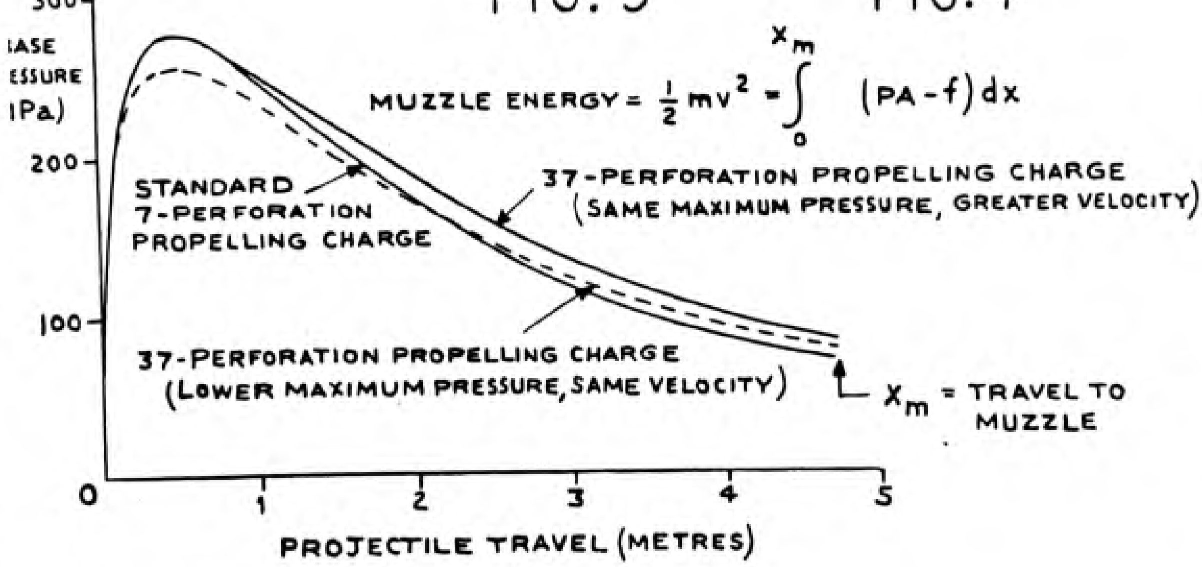


FIG. 4



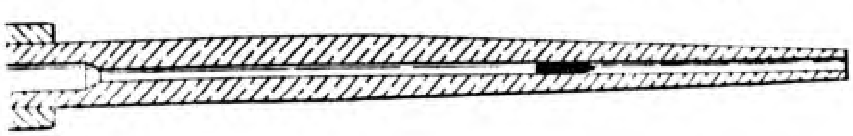


FIG. 5