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METHOD OF PREPARING STAPLE-CONTAINING PROPELLANT GRAINS

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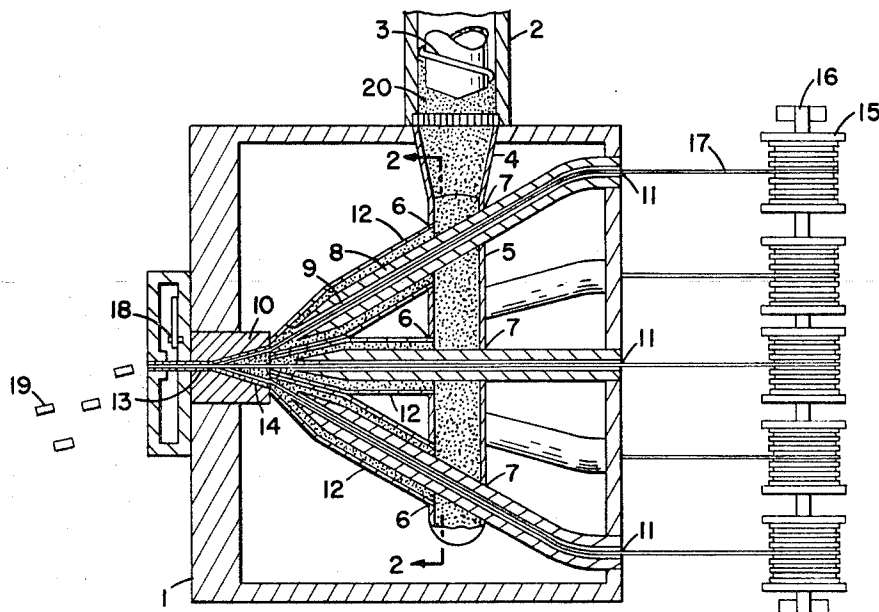


FIG. 1

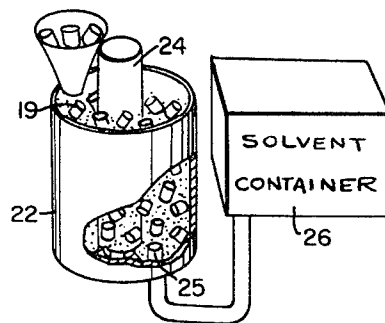


FIG. 4

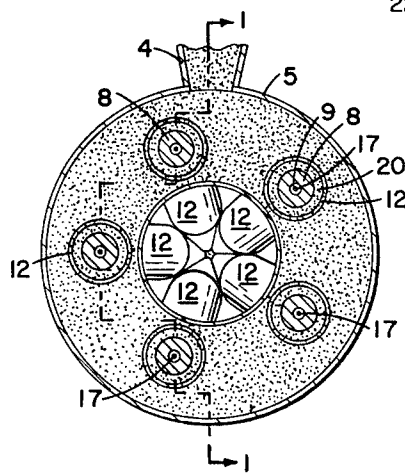


FIG. 2

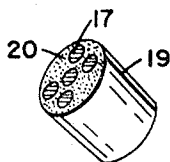


FIG. 3

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METHOD OF PREPARING STAPLE-CONTAINING PROPELLANT GRAINS

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5 Claims

ABSTRACT OF THE DISCLOSURE

Staple-containing propellant grains are prepared by extruding strands of all of the propellant ingredients except the plasticizer around a continuous metal wire. The extruded strands are chopped into short pellets and the pellets are disposed in a mold. Liquid plasticizer is then introduced, and the grain is cured. In this process, degradation of metal staples during mixing and cutting of pellets is avoided, and the staples take the form of wires which extend the full length of the pellets. The burning characteristics of the grain are substantially improved by the increased staple length.

This invention described herein may be used by or for the Government for governmental purposes without payment of any royalty.

This invention relates to solid propellants and more particularly to a method of preparing staple-containing solid propellant grains.

Metal staples, that is, thin fragments of metal wire are employed in solid propellant grains to obtain improved burning characteristics. The metal serves to accelerate the propellant burning rate by conducting heat from the burning surface to the interior of the grain. In addition, the staples provide a source of high-energy fuel since the metal employed is normally aluminum, magnesium, zirconium or other metal or alloy which releases a large amount of energy upon combustion.

The term "wire" as employed in this specification refers to elongated metal pieces which can also be strips or filaments, and which are not necessarily circular in cross-section, but which can also be of the cross-sectional shape of a strip. The term "wirelike" refers to similarly-shaped pellets.

Metal staples are used in various types of solid propellants, including high-energy compositions based on plasticized nitrocellulose. Propellants of this type utilize nitrocellulose as the binder and a nitrate ester as plasticizer, with additional fuel and oxidizer materials such as ammonium perchlorate and aluminum powder, along with the metal staples and various minor ingredients, being provided to produce a highly energetic, fast-burning composition.

Staple-containing propellant grains based on plasticized nitrocellulose have been prepared previously in a casting process wherein all of the ingredients except the liquid plasticizer are formed into small pellets; the pellets are placed in a mold, and the plasticizer is introduced to form a continuous grain by its swelling and gelation action. In this process, the pellets are formed by thoroughly mixing all ingredients except the plasticizer with a volatile liquid

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such as an alcohol or an ether to produce a dough-like solid, extruding the mixture through a die and cutting the extruded strand into pellets as it emerges from the die.

The above-described process presents a major disadvantage in that the length of the metal staples in the grain is shorter than desired. In order to obtain maximum enhancement of burning characteristics, the individual staples should extend the entire length of the pellets. Staples of the same length as the pellets are provided in the starting mixture in this process, but their length is substantially reduced during pellet formation. Some of the staples are broken or cut during mixing, and others are cut when the extruded strands are cut into pellets. Under typical conditions, the average length of staples in the product propellant grain is slightly over one-half the starting length.

It is therefore an object of this invention to provide a method of preparing staple-containing propellant grains.

Another object is to provide a method of preparing staple-containing propellant grains based on plasticized nitrocellulose wherein the length of the staples is increased.

Still another object is to provide a method of preparing nitrocellulose-containing pellets for propellant grain formation having metal staples extending the entire length of the pellets.

Other objects and advantages will be apparent from the following detailed description.

In accordance with the present invention, staple-containing propellant grains based on plasticized nitrocellulose compositions are prepared by intimately mixing all ingredients of the composition except the metal staples and the plasticizer with a volatile organic liquid to form a dough-like mixture, extruding the mixture through a die having a small opening, at least one fine metal wire being passed through said opening concurrently with said mixture, whereby a metal-containing strand is formed, cutting the strand to produce short pellets, disposing the pellets as a bed in a mold, adding the plasticizer to the bed and curing the resulting continuous grain. In this process, degradation of metal staples during mixing and cutting of pellets is avoided, and the staples take the form of wire which extends the full length of the pellets. The burning characteristics of the grain are substantially improved by the increased staple length.

The invention is illustrated by the accompanying drawings wherein:

FIG. 1 is a partial section of apparatus for forming metal-containing pellets;

FIG. 2 is a transverse section taken along line 2—2 of FIG. 1;

FIG. 3 is a perspective view of a pellet prepared in the apparatus of FIG. 1; and

FIG. 4 is a perspective view illustrating the casting of a propellant grain using plasticizer and pellets which were prepared in the apparatus of FIG. 1.

Referring to FIG. 1, mechanisms for concurrently feeding a propellant mixture and five wires through a die are depicted inside housing 1. A cylindrical container 2 is disposed on top of the housing, a screw feeder 3 being provided in the container to force the mixture 20 downward. A downwardly tapered inlet 4 extends to a vertically disposed annular manifold 5 having five symmetrically arranged outlets 6 located on its forward face and five

openings 7 opposite thereto and its rear face. A mandrel 8 having an axially disposed opening 9 extending the full length thereof is disposed through each outlet 6 and opening 7 in the manifold. The mandrels are tapered inwardly at the forward end and are inclined toward a die 10 at the front of the housing. Each mandrel extends to a separate wire inlet 11 in the rear of the housing. A generally tubular wall 12 concentric with and spaced apart from each mandrel extends from the front edge of the manifold to the die so as to provide a passageway for the propellant mixture around the outside of each mandrel. Die 10 is provided with a small opening 13 at its forward face communicating with outwardly tapered opening 14 at its rear face, enlarged to provide space for the five mandrel tips. A spool 15 mounted on rod 16 and having a wire 17 wound thereon is provided behind each inlet 11. A rotary cutter 18 is disposed on the front face of the housing adjacent die opening 13. Chopped pellets 19 are shown falling downward from the opening.

FIG. 2 shows the five mandrels 8 with opening 9 inside each mandrel for passage of wire 17. Propellant mixture 20 passes through the space between the outside of the mandrel and wall 12.

FIG. 3 depicts a pellet 19 containing wires 17 extending the full length thereof, the wires being embedded in a matrix of extruded propellant mixture 20.

FIG. 4 depicts pellets 19 (which were prepared in the apparatus of FIG. 1) being cast in a mold 22 around mandrel 24 with plasticizer being added therein from a plasticizer container 26 through inlet pipe 25.

In operation of the above-described apparatus, the propellant mixture is fed downward around each mandrel and through the die. At the same time, a wire is fed through the central opening in each mandrel. The resulting wire-containing strand is chopped into pellets by the cutter as it emerges from the die.

The present invention is broadly applicable to nitrocellulose-base compositions, and the chemical properties of the composition are not critical. All that is required is that a mixture of all the propellant ingredients except the plasticizer, when combined with a volatile liquid, exhibit suitable physical properties for extrusion and pellet formation. Plasticized nitrocellulose-base compositions in which metal staples are employed normally comprise 8 to 40 weight percent nitrocellulose, 20 to 50 weight percent plasticizer, 0 to 20 weight percent powdered metal fuel, 0 to 70 weight percent oxidizer and 1 to 5 weight percent minor additives such as burning rate catalysts, stabilizers and the like. The metal staples are incorporated in the pellets by the present method at a proportion of 1 to 15 weight percent of the propellant grain.

Any of the previously used plasticizers for nitrocellulose may be employed, and nitrate esters such as nitroglycerin, triethylene glycol dinitrate (TEGDN) and hydroxyglycerol trinitrate are preferred. The oxidizer component can be an inorganic nitrate, chlorate or perchlorate salt, with ammonium perchlorate being preferred. Organic oxidizers such as cyclotetramethylenetetranitramine (HMX) or cyclotrimethylenetrinitramine (RDX) may also be employed. The powdered metal fuel can be aluminum, magnesium, zirconium, boron or other metal or alloy which releases a large amount of heat upon combustion, with aluminum being preferred. Minor additives normally employed as stabilizers and burning rate catalysts in propellants of this type include resorcinol, 2-nitrodiphenylamine and lead salts.

The nitrocellulose and all of the other ingredients except the plasticizer are intimately mixed prior to extrusion to ensure uniformity in the composition. A volatile organic liquid, preferably ethyl alcohol, ether or acetone, is also provided in the mixture to enhance mixing and produce a suitable consistency for extrusion. A volume proportion of 20 to 80 percent organic liquid, based on the amount of the other components of the mixture, may be employed. The organic liquid is removed in a subsequent

drying step so that it does not become a component of the propellant composition. Conventional mechanical mixers may be used for preparing the mixture.

The resulting mixture is extruded through a die having a small circular opening to produce a strand, which is chopped into pellets as it emerges. The diameter of the opening can vary from 0.03 to 0.2 inch, and about 0.15 inch is preferred. Pellets larger than 0.2 inch are not satisfactory because of the difficulty of removing all of the organic liquid and obtaining complete penetration of the plasticizer in subsequent processing. At least one, and up to about 50, metal wires are fed through the die opening concurrently with the extruded mixture. Wire having a diameter of .0001 to .0075 inch may be employed, and a diameter of about .0004 inch is preferred. For metal strip, the preferred dimensions are .0001 to .0075 inch thick and .004 to .01 inch wide. A larger number of smaller diameter wires provides greater improvement in heat conduction than the same amount of metal in the form of larger wires so that smaller wires are preferred. The total amount of wire employed is controlled to produce the desired amount of staple in the grain. The wire can be fed into the die opening from multiple spools as shown in the accompanying figure. A die having multiple openings can also be used, the propellant mixture and wires being fed through each opening.

The emerging strand containing the embedded wires or strips is cut into short pellets, preferably of the same length as the pellet diameter. Cutting of the strand is conveniently effected by use of a rotary cutter at the die face, timed to produce the desired length. A pellet length not exceeding about twice the diameter is required to allow random orientation by merely allowing the short pellets to fall into the mold and stack up irregularly as a bed. Random orientation of the wires is then obtained in the product grain except at the local sites occupied by the individual pellets prior to plasticizing. This pattern of orientation provides for more uniform and reproducible burning characteristics than would be obtained if the pellets were aligned parallel to one another.

The cut pellets are subjected to mild heating to remove the volatile liquid prior to addition of the plasticizer. Heating at 120 to 140° F. for a period of 3 to 4 days is suitable for this purpose.

After being dried, the pellets are placed in a mold conforming to the desired grain configuration, normally an elongated cylindrical mold having an axially disposed mandrel at its center to produce an internal perforation extending the full length of the grain. However, this invention is not limited to a particular grain configuration, and any conventional grain can be fabricated by this means.

The liquid plasticizer is poured or otherwise introduced into the mold to fill the space between pellets. Consolidation of the pellet bed into a continuous, near homogeneous body occurs by the swelling and gelation action of the plasticizer in contact with the nitrocellulose.

The resulting solid grain is then cured by mild heating for an extended period, preferably at a temperature of 100 to 140° F. for 5 to 20 days.

Although this invention is described with reference to a particular apparatus, it is not to be understood as so limited. Various changes and modifications in apparatus and procedure may be employed without departing from the scope of the invention, which is limited only as indicated by the appended claims.

What is claimed is:

1. The method of preparing a staple-containing plasticized nitrocellulose-base propellant grain which comprises intimately mixing nitrocellulose, fuel particles and an oxidizer with a volatile organic solvent to form a dough-like mixture, extruding said mixture through a die having a small opening, passing at least one fine continuous metal wire staple through said opening concurrently with said mixture whereby a metal-containing strand is

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formed, cutting said strand into short wirelike pellets, the length of said pellets being about the same as the diameter of said pellets, disposing said pellets as a bed in a mold, adding a plasticizer to said mold whereby a continuous grain is formed and curing said grain.

2. The method of claim 1 wherein the diameter of said opening is from 0.03 to 0.2 inch.

3. The method of claim 2 wherein metal wires .0001 to .0075 inch in diameter are passed through said opening.

4. The method of claim 3 wherein said metal is aluminum, magnesium or zirconium.

5. The method of claim 4 wherein the amount of said metal is 1 to 15 weight percent of said grain.

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