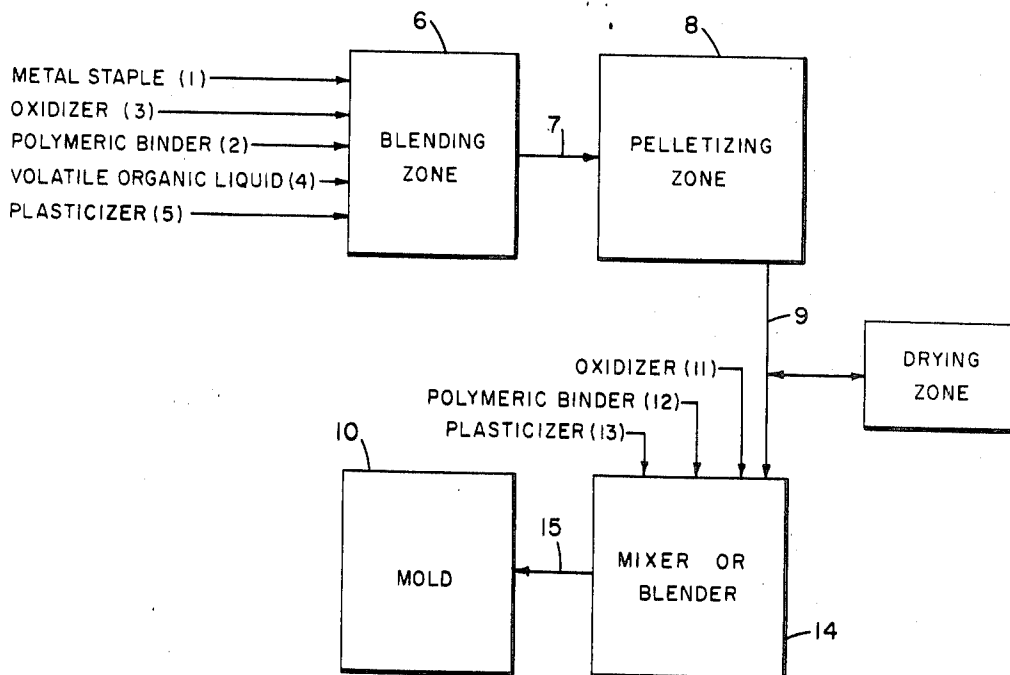


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METHOD OF MAKING A PROPELLANT GRAIN
CONTAINING METAL WIRE STAPLE
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METHOD OF MAKING A PROPELLANT GRAIN CONTAINING METAL WIRE STAPLE

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ABSTRACT OF THE DISCLOSURE

Staple-containing propellant pellet grains are prepared by intimately mixing metal staples with a binder, plasticizer and oxidizer, forming the mixture into small pellets with length approximately equal to diameter, mixing the staple-containing pellets with additional propellant ingredients at a proportion such that the staple-containing pellets comprise 5 to 70 weight percent of the mixture to form a viscous slurry, casting the slurry and curing the resulting grain. Burning characteristics and performance are substantially improved over grains prepared by previous slurry casting methods, because the staples are randomly oriented and not aligned parallel to the motor case wall or motor mandrel.

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

This invention relates to solid propellants and more particularly to a slurry casting process for preparing staple-containing propellant grains.

Metal staples, that is, thin fragments of wire are employed in solid propellant grains to obtain improved burning characteristics. Accelerated burning rates are obtained as a result of increased conduction of heat from the burning surface to the interior of the grain. In addition the staples serve as a source of fuel, the metal employed being aluminum, magnesium, zirconium or other metal or alloy which releases a large amount of heat upon combustion.

The term "wire" as employed in this specification refers to elongated metal pieces which are not necessarily circular in cross-section but which can also be rectangular. The term "wirelike" refers to similarly shaped pellets.

One of the problems presented in the use of metal staples in propellant grains is alignment of the staples in the desired manner. Alignment perpendicular to the burning surface of the grain would provide maximum effectiveness, but this type of alignment has not been attainable in a practical manner. Alignment parallel to the burning surface is undesirable in that a minimum increase in burning rates is realized. Although not as effective as perpendicular alignment, random orientation of staples throughout the grain would provide adequate burning rates, and this type of orientation can be obtained in a practical process as described below.

Control of staple orientation has proven particularly difficult in the preparation of propellant grains by slurry casting. In this process the propellant ingredients including a polymeric binder, plasticizer or other hardening agent, fuel particles and an oxidizer, along with the staples and various minor additives, are combined to form a viscous, dough-like mixture. The mixture is then poured or cast under pressure into a mold of the desired configuration, normally an elongated cylinder having an axially disposed mandrel at the center to produce an internal perforation. During casting, the metal staples tend to become aligned in the direction of flow of the propellant slurry, which is at least partially parallel to the mold and man-

drel walls. As a result the staples in the product grain are aligned parallel to the walls. Grains containing staples oriented in this manner exhibit unfavorable burning characteristics, in particular a high peak and slow final tailoff in the pressure-time trace. In addition, the burning characteristics of grains produced by this process are not sufficiently reproducible owing to differences in the extent of parallel orientation.

It is therefore an object of this invention to provide a method of preparing staple-containing propellant grains wherein the staples are aligned in a substantially random pattern.

Another object is to provide a slurry casting process for preparation of staple-containing propellant grains wherein parallel orientation of staples at the burning surface is avoided.

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

In the present invention staple-containing propellant grains are prepared by intimately mixing metal staples with a polymeric binder, plasticizer or other hardening agent and an oxidizer, forming the mixture into small pellets, mixing the staple-containing pellets with additional propellant ingredients at a proportion such that the staple-containing pellets comprise 5 to 70 weight percent of mixture to form a viscous slurry, casting the slurry and curing the resulting grain.

A preferred embodiment of this invention is illustrated in the flow sheet of the drawing wherein metal staples, oxidizer, polymeric binder, volatile organic liquid and plasticizer are fed via conduits 1, 2, 3, 4 and 5, respectively, to blending zone 6. The blended composition is then removed via conduit 7 to pelletizing zone 8. In pelletizing zone 8, the composition is pelleted to form discrete particles. These pellets are next removed from the pelletizing zone 8 via conduit 9 (for drying). The pellets are then subjected to mild heating to remove the volatile organic liquid. Thereafter, the dried pellets are mixed with the remaining ingredients desired for the particular composition (e.g., more oxidizer, polymeric binder and plasticizer are fed through conduits 11, 12 and 13, respectively, into blender 14 together with the pellets). The mixture is removed from blender 14 via conduit 15 and the mixture is cast into mold 10. The cast grain is then cured.

In this process the staples are incorporated only within the pellets and not throughout the entire mixture so that they do not become aligned in the direction of slurry flow during casting. Orientation of pellets in the grain is random so that staple orientation in the body of the grain is substantially random, with preferential alignment occurring only within the individual pellet sites. Burning characteristics and reproducibility of performance are substantially improved over grains prepared by previous slurry casting methods.

The most critical aspect of the present invention is incorporation of the staples in pellets having sufficient strength for subsequent handling and properties otherwise suitable for use in a propellant grain. The pellets should thus be compatible with the remainder of the grain and they should burn in substantially the same manner. The metal staples may comprise 2 to 20 weight percent of the pellets, the remaining pellet ingredients comprising a polymeric binder, a plasticizer or other hardening agent and an oxidizer. The binder and plasticizer are required for mechanical strength, and the oxidizer provides self-sustaining burning within the pellets. In addition the pellets can contain any of the other ingredients normally used in propellants, for example, powdered metal fuel, stabilizers and burning rate catalysts.

The polymeric binder in the pellet mixture can be nitrocellulose or other rapid-hardening polymer exemplified by polyvinyl chloride and polyethylene. Slower harden-

ing polymers such as butadienes and urethanes are not suitable because of the difficulty of forming these materials into pellets. The polymeric binder may comprise from 10 to 70 weight percent of the pellet mixture. This invention is primarily applicable to plasticize nitrocellulose-base compositions and will be described specifically with reference to the use of nitrocellulose as the polymeric binder.

Any of the previously used plasticizers can be used in the pellets, and for nitrocellulose the nitrate esters exemplified by nitroglycerin, triethyleneglycol dinitrate an hydroxyglycerol trinitrate are preferred. The plasticizer may comprise from 10 to 60 weight percent of the pellet mixture. The oxidizer, which is provided at a proportion 20 to 70 weight percent, can be an inorganic nitrate, chlorate or perchlorate salt, with ammonium perchlorate being preferred. Organic oxidizers such as cyclotetramethylene tetranitramine (HMX) and cyclotrimethylenetrinitramine (RDX) may also be used. Up to 20 weight percent powdered metal fuel may also be provided in the mixture, the metal being aluminum, magnesium, zirconium or other metal or alloy which releases a large amount of energy upon combustion.

The metal staples provided in the pellet mixture are relatively short fragments of fine metal wire. The metal may be any of the previously used staple components such as aluminum, magnesium, zirconium or the like. For metal wire a diameter of .0001 to .0075 inch can be used, and about .004 inch is preferred, the length of the fragments being .100 to .500 inch. In the case of metal strip, a thickness of .0002 to .004 inch, a width of .002 to .050 inch and the same length as for wire can be used.

The staple-containing pellets are formed by mixing the ingredients given above together with a volatile organic liquid to form a dough-like slurry and shaping the slurry. The volatile liquid, preferably ethyl alcohol, ether or acetone is provided in an amount sufficient to produce the desired consistency, a proportion in the range of 20 to 80 volume percent of the remaining ingredients normally being suitable. Although not critical, pellet formation can be conveniently effected by forcing the slurry through a die having multiple openings of the desired pellet diameter and cutting the resulting staple-containing strands as they emerge from the die. The diameter of the pellets can vary from 0.03 to 0.2 inch, and about 0.15 inch is preferred. In order to provide maximum randomization of staples the length of the pellets is relatively short, that is, such as to provide a length-to-diameter ratio less than 2:1, and preferably about 1:1.

The resulting pellets are subjected to mild heating to remove the volatile liquid, a temperature of 120 to 140° F. for a period of 24 hours to 120 hours being suitable for this purpose.

The dried pellets are then mixed with the remaining ingredients desired for the particular composition. The pellets can comprise from 5 to 70 weight percent of the propellant grain, and the remaining 30 to 95 percent can be any of the previously used propellant materials which are compatible with the pellets. In a preferred embodiment nitrocellulose-base pellets, comprising 6 to 40 weight percent nitrocellulose, 20 to 40 weight percent plasticizer, 20 to 70 weight percent oxidizer, 1 to 15 percent metal staples, 0 to 20 weight percent metal powder and 1 to 2 weight percent stabilizers, make up 5 to 70 weight percent of the propellant composition, the remaining components mixed with the pellets being 20 to 40 weight percent plasticizer, 0 to 50 weight percent oxidizer, 5 to 20 weight percent additional nitrocellulose and 0 to 2 weight percent stabilizers.

The composition of the propellant grain may be varied widely to produce the desired specific impulse capability. For example, for more energetic compositions the amount of powdered metal fuel and oxidizer are increased. Where better mechanical properties are required the amount of polymeric binder and plasticizer are increased. The present

method allows a high degree of flexibility in this regard.

In order to avoid breakage of pellets, the other ingredients are preferably thoroughly mixed before the pellets are added. A mixer having a relatively wide blade clearance is required after addition of the pellets to maintain the pellets intact. The viscosity of the slurry propellant mix may be varied by varying oxidizer particle size or plasticizer concentration, viscosity being increased with decreasing oxidizer particle size and with decreasing amounts of plasticizer.

The mixture is cast into a mold conforming to the desired grain configuration, normally a cylindrical shape having an axially disposed internal perforation. Conventional slurry casting techniques may be used in this step.

The cast grain is then cured by mild heating, a temperature of 100 to 140° F. for a period of 5 to 20 days being preferred.

This invention is further illustrated by the following example.

EXAMPLE

Staple-containing pellets .150 inch in diameter and .150 inch long were prepared by mixing the ingredients given below, extruding the mixture and chopping into pellets. The mixture comprised in weight percent nitrocellulose, 28.0; nitroglycerin, 7.5; 2-nitrodiphenylamine, 1.0; resorcinol, 1.0; aluminum powder, 2.0; aluminum wire staple, 8.0; zirconium staple, 2.0; and ammonium perchlorate, 50.0.

The resulting pellets were mixed with other ingredients, and the mixtures so obtained were cast into cylindrical 2 by 7.5 inch rocket motors having a ½ inch axial perforation in the center. The compositions of the propellant grains were as shown in the following table.

PELLET-CONTAINING PROPELLANT COMPOSITIONS

Component, weight percent	Composition No.					
	1	2	3	4	5	6
Pellets	68.2	63.8	57.7	35.0	33.0	21.0
Ball powder (90% nitrocellulose, 8% nitroglycerin, 2% 2-nitrodiphenylamine)	6.4	5.8	13.0	13.0	10.9	
Triethyleneglycol dinitrate	31.8	29.8	26.9	30.0	30.0	31.8
Resorcinol				1.0	1.0	1.0
Ammonium perchlorate		9.6	23.0	23.0		35.3

Rocket motors containing the above-listed compositions were tested by conventional static firing. Burning characteristics were substantially improved over those obtained for staple-containing propellants prepared by conventional slurry casting. In particular the pressure-time traces for the above compositions showed a rapid initial pressure increase which leveled off without a high peak and a rapid tailoff at completion of burning.

The above example is merely illustrative and is not to be understood as limiting 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 propellant grain which comprises intimately mixing metal wire staples with a polymeric binder, a plasticizer and an oxidizer, forming the resulting mixture into small wirelike pellets, mixing said pellets with additional amounts of plasticizer, polymeric binder, oxidizer and powdered fuel at a proportion such that said pellets comprise 5 to 70 weight percent of the resulting mixture, casting the resulting pellet-containing mixture into a mold conforming to the desired grain configuration and curing the resulting cast grain.

2. The method of preparing a staple-containing nitrocellulose-base propellant grain which comprises mixing nitrocellulose with a plasticizer therefor, an oxidizer and metal wire staples at a proportion such as to provide concentrations in weight percent of 10 to 70, 10 to 60, 20 to 70, and 2 to 20, respectively, in the resulting mixture, forming the resulting mixture into small wirelike pellets, mixing said pellets with additional amounts of

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propellant ingredients in the group comprising plasticizers, nitrocellulose, oxidizers and powdered metal fuel at a proportion such that said pellets comprise 5 to 70 weight percent of the resulting mixture, casting the resulting pellet-containing mixture into a mold conforming to the desired grain configuration and during the resulting cast grain.

3. The method of claim 2 wherein said metal is aluminum, zirconium or boron.

4. The method of claim 3 wherein said staples are .001 to .0075 inch in diameter and .1 to .5 inch in length or .0002 to .004 inch thick .002 to .050 inch wide and .1 to .5 inch long.

5. The method of claim 4 wherein said pellets are cylindrical shapes .03 to .2 inch in diameter having a length-to-diameter ratio about one.

6. The method of claim 5 wherein the composition of said pellet-containing mixture in weight percent is pellets 5 to 70, plasticizer 20 to 40, oxidizer 0 to 50, additional nitrocellulose 5 to 20 and stabilizers 0 to 2.

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7. The method of claim 6 wherein said pellets comprise in weight percent nitrocellulose 6 to 40, plasticizer 20 to 40, oxidizer 20 to 70, staples 1 to 15, metal powder 0 to 20 and stabilizers 1 to 2.

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