

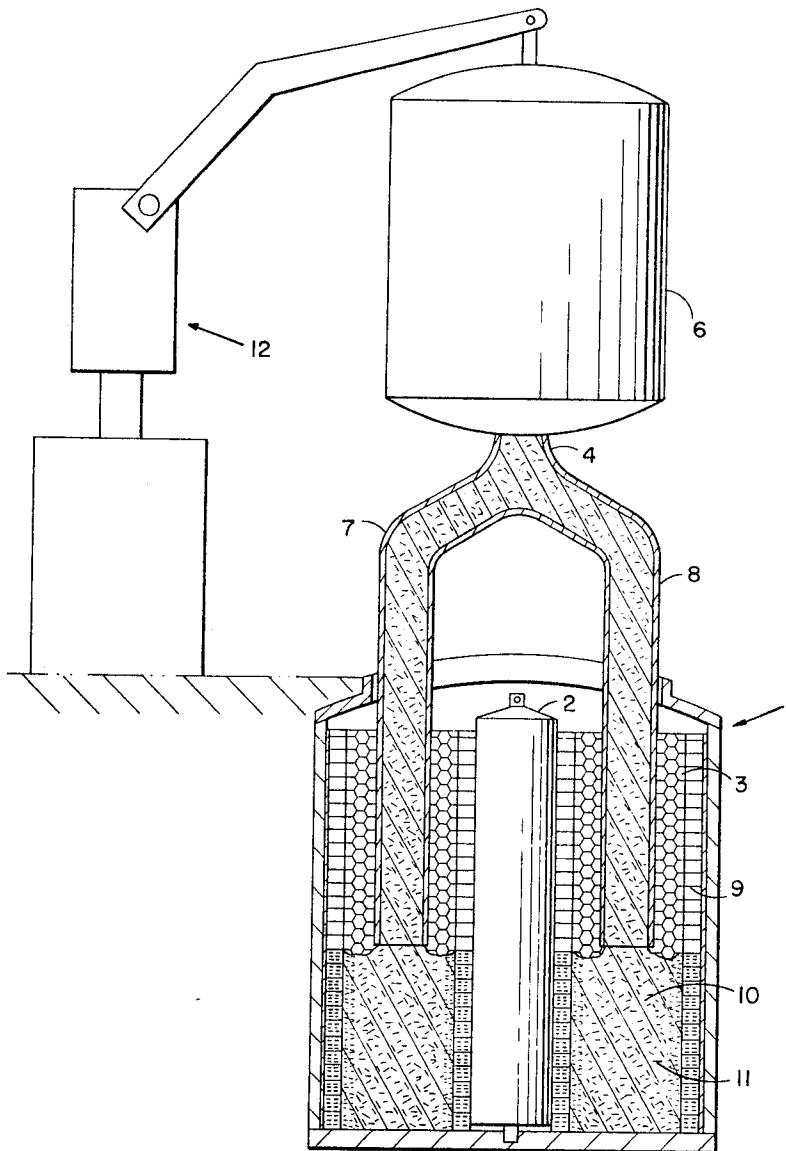
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METHOD OF CASTING STAPLE-CONTAINING PROPELLANT GRAINS AND GRAIN

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

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

Metal staples, that is, thin fragments of metal wire, strip or filament are employed in solid propellant grains to obtain improved burning characteristics. Incorporation of metal staples throughout the grain provides substantially accelerated burning rates by increasing conduction of heat from the burning surface to the interior of the grain. The staples also serve as a source of high energy fuel in the propellant mixture, the metal employed being aluminum, magnesium, zirconium or other metal or alloy which releases a large amount of energy upon combustion. Staple-containing propellants are particularly useful in rapid-accelerating rocket motors that require minimum time from launch to target.

One of the problems presented in the use of metal staples in propellant grains is orientation of the staples in the desired manner. For maximum effectiveness the staples should be oriented with their longest axis perpendicular to the burning surface. Orientation parallel to the burning surface is undesirable in that a minimum increase in burning rate is realized.

Control of staple orientation has proven particularly difficult for propellant grains prepared by slurry casting. In this method the uncured propellant, while in a pasty gel state, is poured under pressure into a mold of the desired configuration, normally an elongated cylindrical container having an axially disposed mandrel in its center to produce an internal perforation. The internal perforation provides a burning surface extending throughout the body of the grain, and the amount of burning surface is controlled by varying the design of the perforation. In casting grains of this type the staples tend to become aligned parallel to the direction of flow of the propellant mixture, which is at least partially parallel to the mold and mandrel walls. As a result the staples are oriented parallel to the burning surface at the internal perforation and outer edge of the grain. Perpendicular, rather than parallel, orientation with respect to the burning surface is particularly desired at these locations. Perpendicular orientation at the internal perforation would provide a high initial burning rate and rapid attainment of maximum thrust. Similarly, perpendicular orientation along the outer wall of the grain would produce rapid burning when the last portions of the propellant are being consumed so as to retain a high thrust for the longest possible period.

It is therefore an object of this invention to provide a method of casting staple-containing propellant grains wherein the staples are oriented perpendicular to the burning surface.

Another object is to provide a cast staple-containing propellant grain having metal staples aligned perpendicular to the internal perforation and outer edge of the grain.

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

In the present invention a solid propellant grain containing metal staples oriented perpendicular to the burn-

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ing surface is prepared by casting an uncured staple-containing propellant mixture in a mold having disposed therein a barrier conforming to the burning surface, the barrier having a multiplicity of uniform, regularly spaced passageways with an effective diameter smaller than the longest axis of the staples. The barrier causes the staples to become aligned perpendicular to the burning surface at the time that the mixture comes in contact with the surface.

The invention is illustrated by the accompanying drawing which is a sectional view of a rocket motor casting assembly.

Referring to the figure, there is shown a generally cylindrical motor case 1 which also serves as a casting mold. A cylindrical mandrel 2 is disposed axially in the motor case to form an internal perforation extending the full length of the resulting grain. Both the inside surface of motor case 1 and the outside surface of mandrel 2 are lined with a honeycomb barrier 3. A casting hose 4 extends downward from a propellant container 6 to casting bayonets 7 and 8 which are positioned within motor case 1. The honeycomb barrier is comprised of a network of open-faced cells 9 for alignment of staples. The motor case is shown partially filled with propellant mixture 10 containing metal staples 11. The staples in that portion of the propellant mixture within the honeycomb barrier are aligned perpendicular to the motor case and mandrel surface while the staples in the remainder of the mixture are aligned randomly or slightly parallel to the direction of propellant flow. The propellant container 6 is lowered during casting by means of a conventional elevator 12.

The propellant grain is formed in the above described assembly by conventional slurry casting techniques, the uncured mixture being poured under pressure into the mold. The only additional feature required by the present invention is the use of a staple-aligning barrier adjacent the mold and mandrel surfaces.

The staple-aligning barrier may comprise any structure having sufficient passageways of the required dimensions to allow complete filling of the space between passageways at the casing surface. The passageways are oriented perpendicular to the surface in order to impart the same orientation to the staples. A structure having maximum interference with flow of the propellant mixture is desired. A honeycomb layer consisting of a network of open-faced hexagonal cells is preferred since it meets these objectives more fully than any other structure. A perforated plate or screen having orifices of the required diameter can also be used, but a larger amount of material would be required. In order to minimize any reduction in energy content of the grain owing to the presence of the barrier, it is preferably constructed of a combustible material which undergoes ignition along with the remainder of the grain. Metals such as aluminum or magnesium, or non-metallic materials such as phenolic or cellulose-type compositions are suitable for this purpose.

The diameter of the barrier passageways is selected to correspond to the size of the metal staples in the propellant mixture. Normally, propellant staples consist of fragments of wire about $\frac{1}{16}$ to $\frac{3}{8}$ inch long and 5 to 20 microns in diameter or metal strips of the same length, .0045 to .04 inch wide and .0008 to .008 inch thick. The effective diameter of the barrier passageways should be smaller than the longest axis of the staples and larger than the shortest axis thereof. A diameter of $\frac{1}{32}$ to $\frac{1}{4}$ inch, depending on the staple length, is preferred. The thickness of the barrier also affects alignment of the staples, more effective alignment being obtained with a thicker barrier having longer passageways. A thickness

of $\frac{1}{8}$ to $\frac{1}{2}$ inch is preferred for the honeycomb layer embodiment.

The method of this invention is broadly applicable to staple containing propellant mixtures which exhibit suitable physical properties in the uncured state for fabrication by casting, and the chemical composition of the mixture is not critical. In general this method is useful for composite-type propellant mixtures comprising a liquid polymeric binder such as polysulfides, polyurethanes, polydienes, polydiene-acrylic acid copolymers and the like; an inorganic oxidizer such as ammonium perchlorate or other nitrate or chlorate salt and other additives such as curing agents and burning rate catalysts along with the metal staples. Propellant mixtures of this type normally contain a relatively large amount such as 50 to 80 weight percent of the solid-phase oxidizer so that the uncured mixture is a thick, dough-like formulation. Metal staples typically comprise about 3 to 7 weight percent of the composition. Other types of staple-containing propellants such as double-base propellants employing nitrocellulose as the polymer binder and a nitrate ester plasticizer may also be fabricated by this method. The viscous propellant mixture normally requires application of superatmospheric pressure, for example, 50 to 60 pounds per square inch, to cause it to flow into the mold. Conventional pressurizing techniques may be employed for this purpose.

The propellant mixture is poured to the desired level in the motor case mold and the resulting propellant grain is cured to impart strength and rigidity therein. Previously known curing methods, which normally involve the application of mild heat for an extended period, may be employed.

Propellant grains prepared as described above exhibit a rapid initial burning rate owing to the perpendicular alignment of metal staples at the surface of the internal perforation and a rapid final burning rate owing to the alignment of the staples adjacent the outer wall of the motor case. These burning characteristics increase the thrust obtainable for a given amount of propellant.

Although this invention is described with reference to a propellant grain having an internal perforation of circular configuration, it is not to be understood as so limited. The configuration of the perforation may be varied as desired to obtain different initial burning rates by varying the design of the mandrel. For example, star-shaped or cruciform designs may be used.

It is also to be understood that various changes and modifications in apparatus and procedure may be employed without departing from the scope of the in-

vention, which is limited only as indicated by the appended claims.

What is claimed is:

1. The method of preparing a propellant grain which comprises casting an uncured, staple-containing propellant mixture into a mold having disposed therein a barrier conforming to and adjacent the wall surfaces of said mold, said barrier having a multiplicity of uniform, regularly spaced passageways with an effective diameter larger than the shortest axis and smaller than the longest axis of said staples, whereby said staples are aligned perpendicular to said surfaces and curing the resulting cast grain.

2. The method of casting a propellant grain of cylindrical, internally perforated configuration which comprises casting an uncured staple-containing propellant mixture into a generally cylindrical mold having a mandrel disposed axially in the center thereof, a barrier being disposed in said mold adjacent the surface of said mold and said mandrel, said barrier being penetrated by a multiplicity of uniform, regularly spaced passageways with an effective diameter smaller than the largest axis of said staples and larger than the smallest axis thereof, whereby said staples are aligned perpendicular to said surfaces and curing the resulting cast grain.

3. The method of claim 2 wherein said barrier is a honeycomb structure consisting of a network of open-faced, hexagonal cells.

4. The method of claim 3 wherein the effective diameter of said cells is $\frac{1}{32}$ to $\frac{1}{4}$ inch.

5. A cast perforated, staple-containing propellant grain comprising a generally cylindrical grain body having an axially disposed perforation extending through the length thereof, a layer of honeycomb material containing staples aligned perpendicular to the surface of said grain being imbedded in said grain adjacent the outer wall and internal perforation.

6. The method of preparing a propellant grain which comprises casting an uncured, staple-containing propellant mixture into a mold having predetermined inner and outer configurations for the propellant and orienting said staples at inner and outer peripheral portions of said propellant perpendicular to the inner and outer surfaces thereof and generally randomly in the remaining portion of the propellant.

No references cited.

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