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SOLVENTLESS EXTRUSION PROCESS FOR FORMING ROCKET PROPELLANT GRAINS

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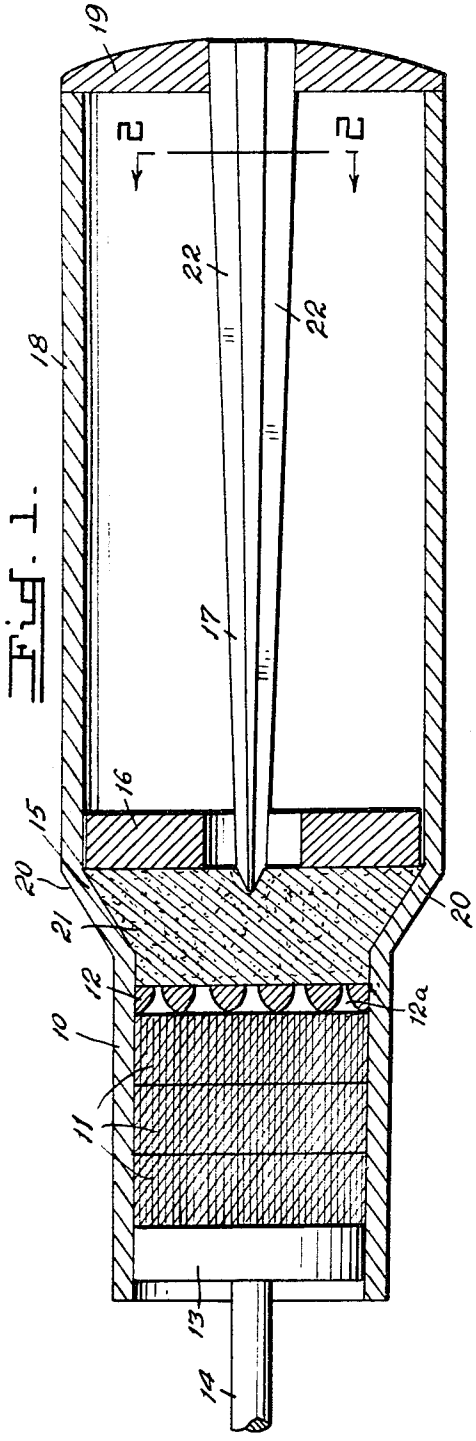



Fig. 1.

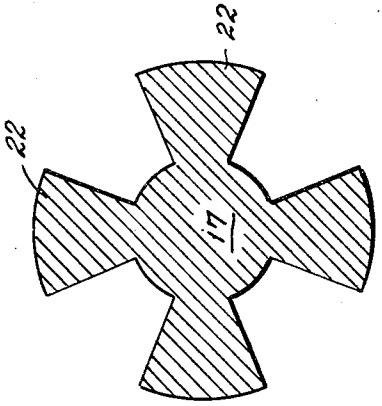



Fig. 2.

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# SOLVENTLESS EXTRUSION PROCESS FOR FORMING ROCKET PROPELLANT GRAINS

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## ABSTRACT OF THE DISCLOSURE

A process for producing a propellant of substantially larger cross-section than that of the propellant material before extrusion, by employing an expansion chamber in which the material is consolidated into a larger grain by the retarding force created by the friction of the moving extruded material against the outwardly tapering metal walls of the guide chamber.

This invention relates to the processing of solid propellant rocket charges, and particularly to a process for manufacturing double-base charges with configurations complexity, overall size and dimensional precision previously unattainable by the conventional extrusion process.

The product of this process has various uses, but may be employed to particular advantage for purposes requiring large and complex shapes, as for example, for the propellant charge in a jet propulsion rocket motor.

Whereas solid propellant charges, of formulations designated composite and double-base, can and are made by processes termed casting, by far the greatest quantity have been produced by the solventless extrusion of double-base formulation, and the majority of the installed manufacturing facilities in this country and elsewhere is of the latter type. This process comprises the mixing of the ingredients, usually in a water suspension, followed by removal of the excess water such as by centrifuging and hot air drying, then subsequent colloiding of the material on heated revolving rolls to form leathery sheets of propellant 0.1 in. thick. These sheets are convolute wound into rolls, and in this form inserted into a press, from which the propellant is forced, under high pressure, through a forming die. This die has a diminishing cross-sectional area, or approach section, followed by a length of uniform cross-section and, if the final product so requires, has one or more pins or stakes, that produce suitable perforations axially through the extruded product. Issuing from the press therefore, is a consolidated propellant strand of uniform cross-section but considerably smaller than before extrusion. The step of extrusion introduces stresses which must be relieved by high temperature annealing in order to fully stabilize the strain created. Also, the dynamic formation reflects the presence of irreducible batch to batch variation in the chemical and physical variations of ingredients, variations in all previous processing stages, and variations in the extrusion conditions, to a degree that the cross-section dimensions of the extruded grains vary sufficiently as to require subsequent machining to avoid excessive variation of ballistic properties among a quantity of rockets loaded with propellant charges made by the solventless extrusion process.

In the consolidation of the roll charge into a homogeneous strand, it is well understood by the industry that the individual strips comprising the roll are welded together in the approach section of die by pressure and dynamic flow, coupled with a continuing reduction in cross-sectional area in the approach section of the die. The minimum percentage reduction in cross-sectional area necessary for consolidation varies with propellant composition and extrusion temperature, but is generally conceded to be about 300%. Thus a standard press, having a basket 16 in. in diameter, can produce as a solid strand product not larger than 9 in. in diameter. Thus, the solventless extrusion process can produce only a small diameter product, only an axially symmetrical product, only a product having undesired internal stresses and a product that requires machining to eliminate variations in cross-sectional dimensions.



It is therefore, the object of this invention to eliminate the above restrictions by enlarging the die so that it contains the entire finished charge and accomplishing the consolidation of the charge through the combination of a multiplicity of small orifices located at the entrance to the die and a retarding force that is asserted immediately downstream of said orifices.

In the drawing:

FIGURE 1 of the drawing is a diagrammatical illustration of the apparatus employed in carrying out the process of this invention;

FIGURE 2 is an enlarged cross-section of the stake taken on the 2—2 line of FIGURE 1.

In the drawing, the press basket **10** is filled with sheets of propellant **11** which are extruded through partition **12** having a multiplicity of orifices **12***a* by the extrusion ram **13** which is powered through a shaft **14**. The extruded material passes into a guide chamber **15** of greater diameter and/or greater cross-sectional area. The movement of the extruded material is opposed or retarded by a consolidation ram **16** which maintains a friction tight fit at the perimeter and slides loosely on a tapered stake **17** held in a centered position in the die **18** by a cap **19**. The ram **16** supplies the initial retarding force necessary to push the extruded material against the expanding walls **20**, so that instead of making a propellant grain smaller than the press basket as is the usual custom, is the means that permits a much larger grain to be formed in the die. This retarding force also performs the additional function of retaining the expanded material in the guide chamber long enough to relieve the strains in the material caused by extrusion. The ram **16** supplies the retarding force when starting the operation, however once the ram is moved to the end of the die **18** and removed, the retarding force is supplied by the friction in the guide chamber **15** of the solid mass of **21** against the walls **20**. This friction continues to supply the retarding force necessary in succeeding operations and this force continues to perform the dual function of consolidating the extruded material so that it is possible to make considerably larger grain than the receptacle from which the material is extruded and at the same time while performing the consolidation function retaining the expanded material a sufficient period to relieve stresses and strains built up by the extrusion. When the dies **18** is filled with material, the die which contains a heating means (not shown) anneals the grain and the stake **17** is withdrawn by means of the cap **19**. The stake **17** is tapered in a direction opposite to the flow of material and has longitudinal projections **22** tapered in direction opposite to the stake and tapered axially towards the center which govern the interior shape of the grain and which may be varied by changing the shape of the stake so that many geometrical configurations may be left in the interior of the grain depending upon the burning characteristics desired for any particular grain. Thereafter the cured grain may be removed from the die and the process continues without the ram **16** used in the initial operation by reason of the friction generated, by the movement of the mass **21** of the extruded material against the expanding walls **20** of the guide chamber **15**, supplying the retarding force necessary to produce a better and much larger grain.

The retarding force so essential to the operation of this

invention was observed in the normal operation of extruding small diameter grains and appeared to occur possibly one in a million extrusions and changes were made to prevent a recurrence of this occasional action. This observation revealed that the product occasionally touched and adhered to a nonfunctional, larger diameter metal sleeve and that the mass enlarged to fill the larger sleeve even though no back pressure was exerted. Thus, it is concluded that the powder to metal friction alone accomplishes the enlargement.

In the adaptation of this concept in actual practice, tests were found to be completely satisfactory, however, the first few inches of the product were not consolidated and had to be cut-off. Therefore, to avoid waste on the initial run, a plywood disk or ram was utilized and sized so that it was a friction fit with the inside diameter of the mold and a very loose fit around the tapered stake, with a clearance of one to two inches, which further demonstrates that substantial back pressure is not required. The ram was not used after the initial extrusion, the first charge being cut free from the press basket in the area facing the ram **16** leaving a heel of consolidated extruded powder that acts as the consolidation ram for each succeeding extrusion.

One of the advantages of this process is that the pressure in the mold is extremely low and the mold need be only sufficiently rigid to insure desired dimensional tolerances. Therefore equipment of nominal capital investment may be used to replace expensive equipment limited to a product of small diameter, for example nine to ten inches and at the same time produce a much larger more desirable product that may be axially unsymmetrical or contain other desired geometrical configurations within the grain.

What is claimed is:

**1.** A method for the solventless extrusion of solid propellant for rocket charges comprising, extruding a propellant material from a press basket through a multiplicity of small orifices into a guide chamber of increasing cross-sectional area in the direction of flow of the extruded material and utilizing the resistance supplied by the friction of the extruded material against the expanding walls of the guide chamber to provide the retarding force necessary for the spreading of the extruded material in the larger area of the guide chamber and retaining the material in the guide chamber long enough to relieve internal extrusion strains therein.

**2.** A method for the solventless extrusion of solid propellant for rocket charges comprising,

loading a press basket with sheets of propellant,

extruding from the press basket the propellant material through a multiplicity of small orifices into a guide chamber of increasing cross-sectional area against an initial retarding force exerted by a consolidation ram and thereafter

utilizing the friction of the extruded material against the expanding walls of the guide chamber to cause a delay sufficient to provide both for a continuing retarding force for succeeding extrusions and for retaining the expanding material in the guide chamber long enough to relieve the internal extrusion strains existing therein.



**3.** A method for the solventless extrusion of solid propellant for rocket charges comprising, loading a pressure basket with sheets of propellant, extruding the propellant material through a multiplicity of small orifices against an initial retarding force into a guide chamber of increasing cross-sectional area from the pressure basket in the direction of flow of the propellant material, employing a ram loosely slidable on a tapered stake centered in the die as the initial retarding force against the movement of the material through the guide chamber and die, thereafter utilizing the friction of the extruded material against the expanding guide walls of the chamber to provide sufficient resistance both for the necessary retarding force for succeeding extrusions and retaining the expanding material in the guide chamber long enough to relieve the internal strains existing therein and moving material from the exit of the guide chamber to a die of the same cross-sectional area as the exit of the guide chamber around said stake centered therein to form a rocket grain of greater diameter than the press basket and having internal geometrical configurations regulated by the shape of the stake employed.

**4.** A method for the solventless extrusion of solid propellant for rocket charges comprising, loading a pressure basket with sheets of propellant, extruding the propellant material through a multiplicity of small orifices against an initial retarding force into a guide chamber of increasing cross-sectional area from the pressure basket in the direction of flow of the material, thereafter utilizing the friction of the extruded material against the expanding walls of the guide chamber to provide sufficient resistance both for the retarding force for succeeding extrusions and slowing the movement of the extruded material through the guide chamber to relieve the stress within the expanding material, feeding the extruded material to a heated cylindrical die around a stake with longitudinal projections centered therein and tapered in a direction opposite to the flow of the material, holding the material in the heated die to completely anneal the finished grain and removing the stake to leave the desired geometrical configurations in the interior of the grain.

**5.** A method for the solventless extrusion of solid propellant for rocket charges comprising, loading a pressure basket with sheets of propellant, extruding the propellant material through a multiplicity of small orifices into an expanding guide chamber, moving the extruded material into a die of greater diameter than the press basket against the retarding force produced by the friction of the material against the expanding walls of the guide chamber, annealing the extruded material in the die for the production of a propellant grain of much larger diameter than the press basket due to the utilization of the retarding force of the guide chamber.


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