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Gilbert
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[54] AUTOMATIC PROPELLANT FEED SYSTEM

[75] Inventor: **Bruce Gilbert,** Waco, Tex.

[73] Assignee: **North American Rockwell Corporation,** El Segundo, Calif.

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[52] **U.S. Cl.** **86/1,** 156/429, 264/3, 264/176

[51] **Int. Cl.** **B31c 1/00,** F42b 33/10

[58] **Field of Search** ....86/1, 20; 264/3, 264/3 B, 176, 177, 212; 156/244, 429–431; 18/12 DR, 13 A, 13 N, 13 P; 161/60, 55

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Primary Examiner—Benjamin A. Borchelt
Assistant Examiner—H. J. Tudor
Attorney—William R. Lane, Thomas S. MacDonald and John E. Kelly

[57] **ABSTRACT**

Apparatus and process for making filament reinforced solid propellant grains by automatically extruding uncured propellant and winding filaments onto a rotating grain-forming mandrel. Heatable compactor blades, underlying the mandrel, spread the propellant evenly and lower its viscosity if necessary as the propellant is applied from a plurality of extruders. The compactor blades and extruders are interconnected to simultaneously move toward and away from the mandrel.

12 Claims, 6 Drawing Figures

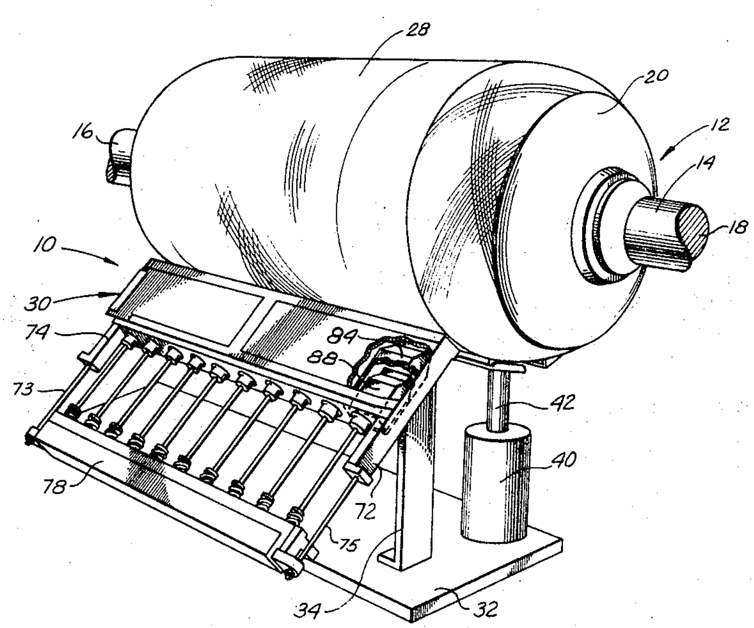


FIG 1

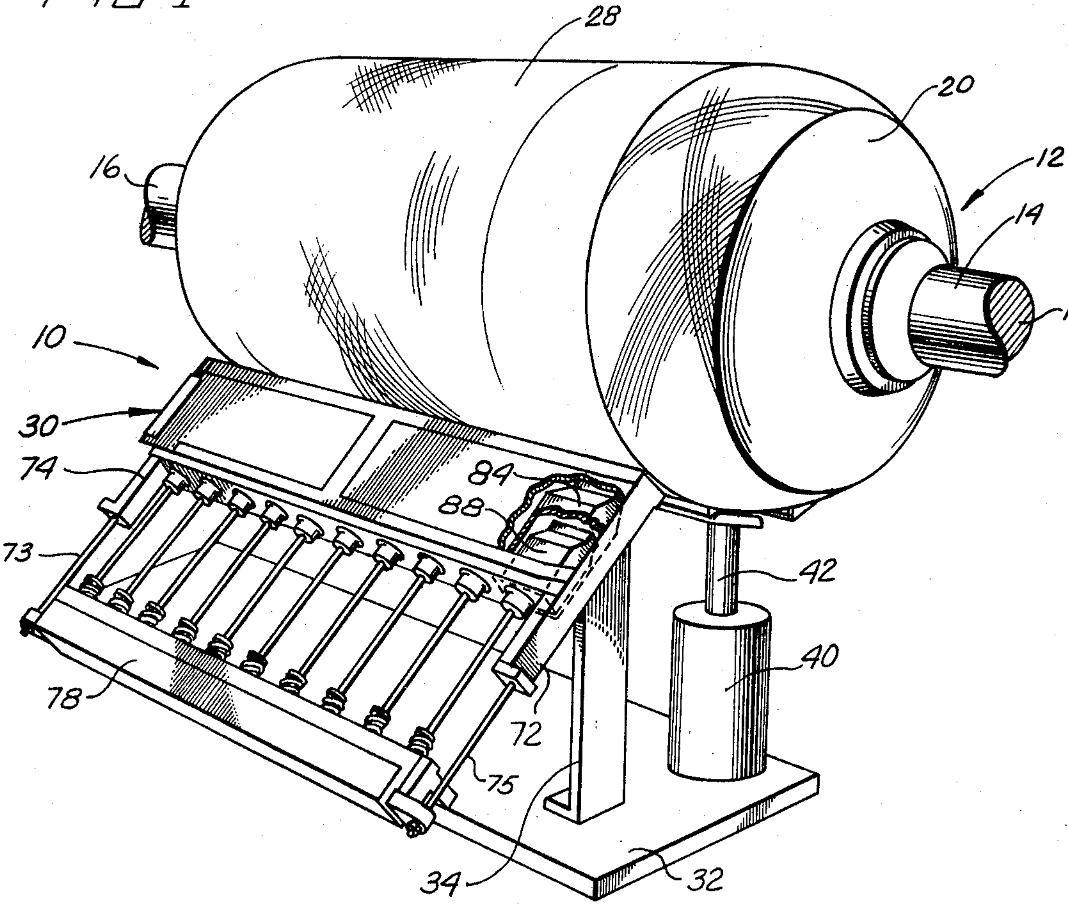
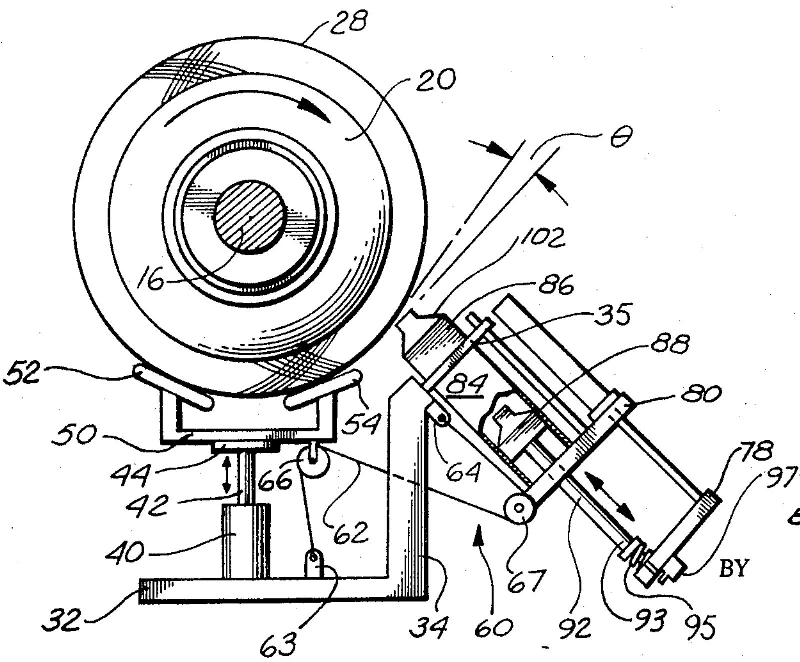


FIG. 3



INVENTOR.
BRUCE GILBERT

BY John E Kelly

AGENT

FIG. 2

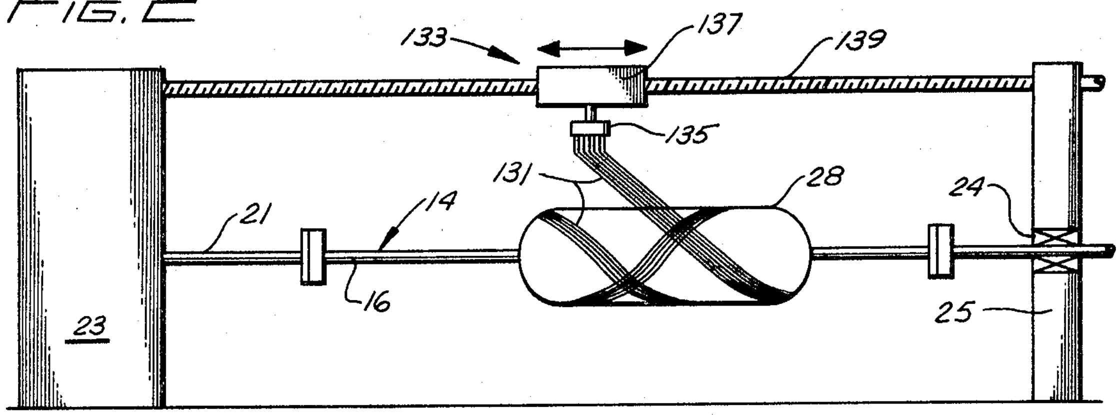


FIG. 4

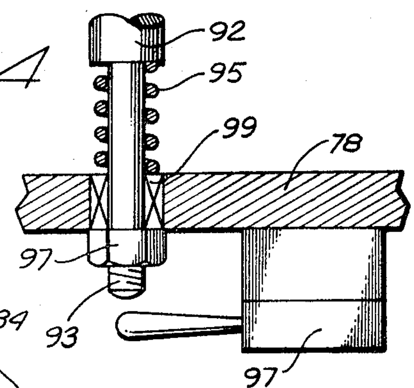


FIG. 6

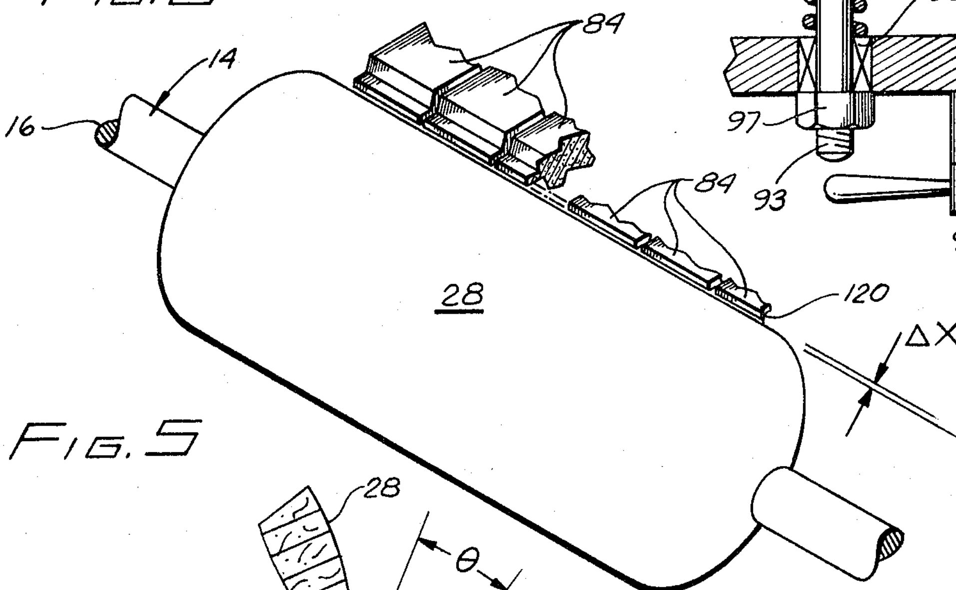
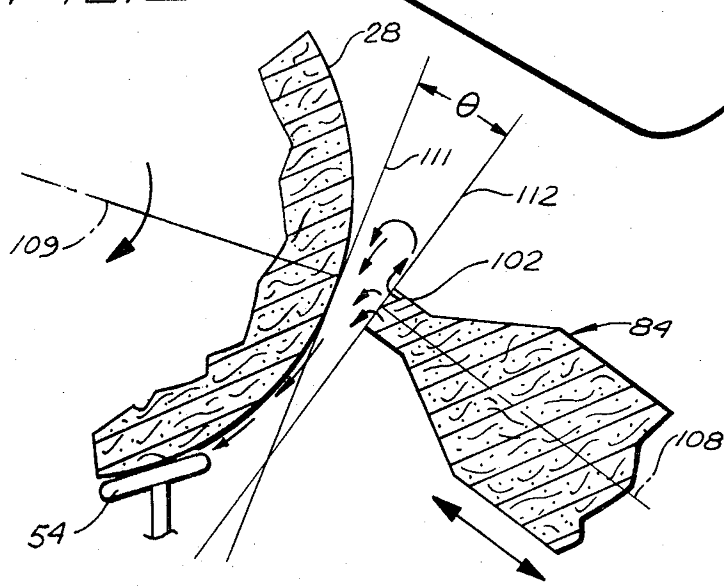


FIG. 5



INVENTOR.
BRUCE GILBERT

BY John E Kelly

AGENT

AUTOMATIC PROPELLANT FEED SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to a procedure and apparatus for fabricating reinforced solid propellant grains of the type that may be used in constructing rocket motors. The concept of reinforcing solid propellant grains with filament windings to improve the structural integrity and ballistic characteristics of the grain is well established. Casting techniques attempted have generally proven inadequate for producing high performance reinforced grains. From a practical standpoint, the matrix propellant cannot be uniformly spread into a pre-arranged mesh of reinforcing filaments. Forcing the propellant into the mesh results in greatly distorting the mesh pattern and the development of voids due to poor adherence between the filaments and propellant. Resulting high porosity may cause catastrophic results by producing an unpredictably broad burning area. Such a burning area will produce intense combustion product pressures that may burst the rocket motor casing.

Another approach to fabricating reinforced grains, with which the instant invention is most closely related, is a process involving numerous hand manipulations and great time consumption while exposing the workmen to severe risks due to the volatile nature of the process. A customary technique involves the use of a caulking gun containing a charge of pressurized propellant which is manually deposited upon a grain-forming mandrel rotatable about its longitudinal axis. Unsymmetrical grains often result and therefore must be rejected due to the difficulty in synchronizing the rate of extrusion and the rotation rate of the mandrel. Attempts to smooth and evenly spread the propellant soon after it is deposited on the mandrel with hand spatulas or the like is difficult, especially in cases where the propellant is highly viscous. During the periods of extrusion and non-extrusion, reinforcing filaments are spirally wound over the mandrel or onto the preceding covering of propellant. When propellant coverings are of non-uniform thickness, subsequently wound filament layers will also be irregular, thus producing a defective grain.

SUMMARY OF THE INVENTION

Briefly described, the instant invention comprehends a procedure and apparatus for fabricating tubular shaped reinforced propellant grains of a type that may be incorporated in a rocket motor, for example. A continuously operating filament winding device travels back and forth relative to the axis of a rotatable grain-forming core winding filaments onto the core. Disposed on one side of the core are a plurality of upwardly inclined grain extruders having edge abutting extruder nozzles whose combined overall lengths define a discontinuous narrow slot constituting the length of the grain to be formed. The slot is substantially coextensive with the end to end length of the core. In its operating position the slot is spaced a slight distance from the core sufficient to permit the grain material being extruded from the individual nozzles to merge and become a continuous ribbon that is deposited onto the core, covering its entire periphery through one complete revolution of the core. Beneath the core is positioned a pair of spaced compacting blades that serve the two-fold purpose of compacting and evenly distributing the uncured propellant and also smoothing out furrows and irregularities in the grain caused by the penetration of the filaments being wound onto the core. Optionally the compactor blades are heatable so that the viscosity of fast curing materials and the like may be sufficiently lowered to make the material more amenable to shaping. To avoid the tendency of the grain material to pull loose, fall away and become wasted immediately after it is deposited onto the core, the axes of the extruders are inclined within a range from 0 degrees to 15 degrees relative to the radial line of the core passing through the zone on the core periphery where the propellant is being deposited.

The filament winding is continuous while the feeding is intermittent. The feeding is commenced after a predetermined thickness of filament build-up has been accomplished and the feeding cycle is discontinued after a full revolution of the core at which time a complete cover of uncured grain will have been deposited onto the core. The compactor blades and grain extruders are interconnected so that they may be simultaneously moved to or retracted from their operating positions. Inasmuch as the apparatus and procedure in accordance with this invention can be practiced from a remote location, the peril to the operators who heretofore had to be in the immediate proximity of the explosive material is eliminated. A desired symmetrical grain of high integrity and reliability is fabricated at a substantial diminution of costs in terms of funds and man hours.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of apparatus for fabricating reinforced grains with a section of the plural extruder assembly removed to show the details of a single extruder;

FIG. 2 is a schematic representation of a filament winding device shown winding reinforcing filaments onto a grain-forming core;

FIG. 3 is a schematic end view of the apparatus showing the compactor blade assembly and more details of the extrusion assembly;

FIG. 4 is a detailed view, partially in section, showing a safety electrical switch capable of discontinuing the extruding operation;

FIG. 5 is a sectional view taken along a plane that passes laterally through an individual extruder and the grain and core assembly showing the extruder orientation relative to the surface portion of the grain onto which new grain is being deposited; and

FIG. 6 is a perspective fragmentary view showing a plurality of extruders whose individual nozzles define a discontinuous slit that is slightly spaced from the core.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and especially to FIG. 1 there is shown a solid propellant grain making apparatus **10** having a rotatable mandrel assembly **12** and a propellant feed assembly **30**. Extending through the longitudinal axis of mandrel **12** is a rotatable spindle **14**. As shown schematically in FIG. 2, spindle **14** has one end **16** connected to a motor drive shaft **21** connected to a drive assembly **23**. Its other end **18** is suitably journalled for rotation in a stationary bearing **24** formed in a rigid upright plate **25**. Rigidly mounted on the intermediate region of spindle **14**, as shown in FIG. **1**, is a grain-forming core **20** on which a tubular shaped propellant grain **28** may be fabricated. When grain **28** is fully built, its interior periphery will be flush with the exterior periphery of core **20**.

Propellant feed mechanism **30** is provided for extruding a matrix propellant onto core **20** and gradually building up grain **28** to the desired dimensions. Feed mechanism **30** has a base plate **32** which may be mounted on wheels (not shown) and an upright frame **34**. Anchored to base plate **32** are two fluid actuated cylinders **40** (only one being shown) each having a piston **42**. As schematically depicted in FIG. **3**, piston **42** is connected to a ram head **44** which in turn is fixed to a yoke **50**. The arms of yoke **50** are erect and secured to a pair of upwardly diverging blades **52** and **54**. Blades **52** and **54**, as will be more fully explained below, are heatable and operate to compact and evenly spread extruded propellant as the propellant grain is being constructed. The line of intersection of the planes in which blades **52** and **54** lie is parallel to and lies in a vertical plane with the longitudinal axis of spindle **14**. The longitudinal lengths of blades **52** and **54** are substantially coextensive with the end to end length of core **20**.

Connected to the top of frame **34** is a bracket **35** that serves as a guide-way through which propellant feed assembly **30** may slide. A pulley assembly **60** includes a tension cord **62** whose opposite ends are rigidly secured to an eyebolt **63** on base plate **32** and an eyebolt **64** on frame **34**. Intermediate portions of cord **62** are looped over an idler pulley **66** attached to yoke **50** and an idler pulley **67** secured to extrusion assembly **30**. To promote superior extrusion, assembly **30** may be inclined to a vertical plane through core at between **25** and **65** degrees. When yoke **50** that supports compactor blades **52** and **54** is thrust upwardly by cylinder **40**, slack in chord **62** will be taken up causing propellant extrusion assembly **30** to slide upwardly toward core **20**. Conversely, retraction of yoke **50** automatically causes propellant feed assembly **30** to be withdrawn from core **20** under the force of gravity and a spring loaded mechanism (not shown).

On the opposite sides of propellant feed assembly **30** is a pair of pneumatic cylinders **72** and **74**. As shown in FIG. **1**, the lower distal ends of piston rods **73** and **75**, associated with cylinders **72** and **74** respectively, are connected to a horizontally extending base bar **78**. Parallel to base bar **78** is a transverse bar **80**, most clearly shown in FIG. **3**, whose opposite ends are threadably connected to the inner walls of cylinders **72** and **74**. Disposed between cylinders **72** and **74** is a bank of individual propellant extruders **84**. Each extruder **84** has a cartridge **86** for containing a charge of matrix propellant material to be extruded and a piston head **88** connected to a ram rod **92**. As most clearly shown in FIG. **4**, the lower end **93** of each rod **92** is connected to base bar **78** by way of a coiled compression spring **95** and lock **97**. If a pressure overload condition arises in the extrusion assembly during extrusion, the grain being fabricated may be defective. From the standpoint of quality control and safety it is desirable therefore to temporarily terminate the extrusion operation until the trouble source is remedied. This type of condition to be avoided may, for example, result from excessive force being applied to ram rods **92** and bar **78** or when propellant flow is clogged or irregular, e.g., due to high viscosity propellant causing a pressure backup. To detect and correct these conditions, a safety switch **97** is positioned slightly below the tip of rod end **93**. Excessive compression stress exerted on spring **95** forces end **93** to slide through a bearing **99** until it contacts safety switch **97**. Then through a suitable electrical circuit (not shown) the extruding operation is terminated so that the trouble source can be investigated.

The upper end of each individual extruder **84** as shown in FIGS. **3** and **5** terminates in an extrusion nozzle **102**. As best shown in FIG. **6**, the nozzles **102** of extruders **84** are aligned in edge abutting relationship constituting discontinuous or interrupted slot **120**. Slot **120** is separated by a distance ΔX, preferably 1/16 inch, from core **20**. As the grain fabrication continues, the distance ΔX is maintained relative to the built-up portion of the grain. It should be noted that for the sake of clarity and to avoid duplicated descriptions, the term core is often intended to comprehend both core **20** and the built up portion of uncompleted grain **28**. Referring again to FIG. **5**, extruder axis **108** of extruder **84** is shown slightly inclined by an angle θ relative to radius line **109**. Radius line **109** passes through the zone of grain **28** onto which propellant is being deposited. Differently stated, angle θ is defined by the tangent plane passing through the zone of grain **28** onto which propellant is being fed and a plane **112** that is oriented perpendicularly to extruder axis **108**. Maintaining the inclination of angle θ during extrusion tends to prevent the spilling or falling away of propellant from the outer surface of grain **28**. Angle θ is adjustable and is dictated by such parameters as the surface velocity of grain **28**, feed rate and viscosity of the matrix propellant and type of propellant being employed. Thus the function of maintaining the angle θ is to assure an optimum mechanical interlock, i.e., adherence between the matrix propellant material being extruded with the grain and reinforcing filaments. It has been found that if angle θ is considerably less than optimum then the matrix propellant may not become sufficiently pressed onto the moving surface of grain **28**, the resulting poor adherence causing propellant to fall away and become wasted. To the other extreme, if angle θ is opened too wide, then the pressurized propellant will tend to flow backwardly over the top of the extrusion nozzles and away from the grain producing considerable waste. Depending upon the above mentioned parameters, angle θ may be optimum within a range of from 0° to 15°.

As a newly extruded covering of propellant encounters first compacting blade **54** and then compacting blade **52**, as shown in FIG. **3**, uneven or irregular areas of propellant are spread out so that a covering of uniform thickness is achieved. The upward pressure from fluid cylinder **40**, exerted on blades **52** and **54**, causes them to lightly engage the adjacent grain surface being formed so that the newly applied propellant covering is intimately commingled with the reinforcing filaments and grain surface. It is contemplated that while the winding operation may be continuous, the propellant feed operation will be intermittent. During periods when the propellant feed operation is suspended the reinforcing filaments being applied sink into the grain surface tending to develop furrows and rippling. If these resulting surface irregularities and voids were not eliminated, they would drastically impair the overall grain performance and integrity. Therefore, it is the function of blades **52** and **54** to smooth over the grain surface so that the desired intimate bonding and grain geometry is attained. For some types of propellant it may be desirable to heat the compacting blades **52** and **54**, for example, by way of a hot fluid circulating system or electrical heating system (not shown) so as to lower the viscosity of the propellant to make it more amenable to shaping.

Before the first covering of matrix propellant is fed onto core **20**, a suitable criss-cross pattern of load bearing reinforcing filaments is spirally wound on core **20**. While the particular technique or apparatus for winding the filaments onto core **20** is not an important part of this invention, an adequate technique and apparatus is disclosed in a U. S. Patent application, Ser. No. 179,466, filed Mar. 19, 1962, which application has been assigned to the assignee of this invention. In part, the invention of the application concerns a device and method for winding reinforcing filament into a propellant grain which may revolve about its longitudinal axis as the device travels longitudinally relative to its axis or vice versa. Core **20** may be constructed of detachable Teflon coated steel components or in the alternative may be constructed of water soluble composition such as sand with polyvinyl alcohol. In the latter case, core **20** would be dissolved in accordance with the well known lost-wax techniques after propellant cure. As schematically depicted in FIG. **2**, reinforcing filament wires **131** are wound over grain **28** by a winding device **133**. Filaments **131** issue under pretension from a multi-wire delivery head **135** that is supplied from a supply spool (not shown). During the winding operation a carriage **137** that mounts delivery head **135** travels back and forth upon a rotatable track **139**. As mentioned in the U. S. Application, the winding device may be stationary as the solid grain being fabricated simultaneously rotates and travels back nd forth relative to its longitudinal axis.

In constructing a reinforced propellant grain in accordance with this invention, first winding device **133** is operated until a pattern of filament wires of a predetermined thickness is applied to core **20**. Then, referring to FIG. **3**, cylinder **40** operates to elevate compacting blades **52** and **54** into engagement with the bottom side of core **20**. At this point with the winding operation either continuing or suspended and with propellant extruders **84** advanced to their feeding positions, base bar **78** is actuated to cause piston heads **88** to penetrate deeper into their respective cartridges **86**. The uncured matrix propellant charges now under compression are expressed from their respective noozles **102**. Referring to FIG. **6**, the propellant material passes through discontinuous slit **120** and across the slight gap ΔX as a continuous ribbon of uniform thickness. The ribbon is driven into the pores and voids defined by the filament sections of the winding pattern. Propellant extrusion continues through one complete revolution of core **20** at which time extruding is temporarily terminated while the winding operation continues through another cycle. The feed rate at which the propellant is discharged initially onto core **20** and subsequently onto grain **28** is predetermined so that proper adherence is attained. After a second filament pattern of proper thickness is wound onto grain **28** the extrusion operation is commenced once again and continues throughout another revolution of core **20**. When filament wire of 0.0075 inch diameter is used, the winding operation will proceed through fifty or more revolutions before a cover of propellant is fed onto the grain.

As grain **28** is continuously built-up, its outer diameter becomes enlarged forcing blades **52** and **54** to gradually descend so that their pressure against the grain remains constant. Since yoke **50** is interlinked by pulley assembly **60** with feed assembly **30**, the individual extruders **84** are simultaneously withdrawn from grain **28** so as to maintain a constant gap ΔX. By maintaining a constant compacting pressure against grain **28** and a constant feed condition of propellant onto grain **28**, a grain of high integrity and the desired contouring is achieved.

Since the grain fabrication technique is essentially fully automatic it can be operated from a remote location thereby eliminating the exposure of personnel to potential hazards. The simultaneous operations of the individual extruders **84** to produce continuous ribbon of propellant that extends over the entire length of the grain serves to greatly improve built-up uniformity while reducing the hazard of air inclusions. As mentioned in the case of propellant compound of relatively high viscosity, the heat supplied from compactor blades **52** and **54** lowers the propellant viscosity so that the propellant can be more easily spread and worked. Due to the fact that in the individual extruders **84** are inclined at a predetermined optimum angle θ the potential waste of propellant is substantially eliminated. Once the propellant is initially adhered to the surface of grain **28**, its tendency to roll and pull loose from the grain is eliminated because of the spreading and compacting force exerted by blades **52** and **54**.

While the particular composition of the reinforced solid grain does not form an important part of this invention, for purposes of illustration, the reinforcing filaments may be metallic wires used as fuel such as aluminum or magnesium constituting approximately 5 to 16 percent of the overall grain weight. The grain may also include an ammonium perchlorate oxidizer constituting 60 to 80 percent of the grain weight and a suitable binder and other additives such as curing agents in the order of 1 to 30 percent of the overall grain weight. The use of any other suitable fuels, oxidizers, binders and curing agents such as those mentioned in the co-pending application is also within the scope of this invention.

While a particular embodiment has been chosen for best illustrating the particular uniqueness and advantages of the instant invention, it should be made clear that the scope and spirit of the invention is to be limited only by the following claims.

I claim:

1. A device for making a reinforced structure comprising;

a rotatable structure-forming core,

feeding means for feeding uncured structural material onto the core as it is rotating, the feeding means including a cartridge for containing uncured structural material in communication with an elongated narrow extrusion slit whose length is equal to the length of the structure to be formed,

means to move said feeding means radially inwardly and outwardly with respect to said core,

winding means for winding reinforcing filaments onto the structure as it is being formed, and

compacting means circumferentially spaced from said feeding means for compacting the uncured structure to make it of substantially uniform thickness.

2. The device according to claim 1 wherein the feeding means comprises an assembly of plural structural material extruders having extrusion nozzles whose combined lengths constitute the end to end length of the structure being formed, said assembly being spaced from said core so that extrusions from said nozzles merge on said core in a single ribbon.

3. The device according to claim 1 wherein the compacting means comprises at least one compacting blade whose length is at least as long as the longitudinal length of the grain to be formed.

4. A device for making a reinforced propellant grain comprising;

a rotatable grain forming core,

feeding means for feeding uncured grain material into the core as it is rotating,

said feeding means including an assembly of plural grain extruders having extrusion nozzles whose combined lengths constitute the end to end length of the grain being formed and wherein each extruder includes a cartridge for containing uncured grain material, a piston inside the cartridge and a ram rod connected to the piston,

said assembly further comprising an actuator for simultaneously operating all of the extruders,

winding means for winding reinforcing filaments onto the grain as it is being formed, and

compacting means for compacting the uncured grain to make it of substantially uniform thickness.

5. The device according to claim 4 further comprising pressure detection means connected to each individual extruder for detecting pressure overload conditions and discontinuing extruding when such condition exists.

6. The device according to claim 5 wherein the pressure indicating means comprises a compression spring disposed between the lower end of each ram rod and the actuator, and an electrical switch positioned adjacent the rod that is activated between the rod when the spring attains a predetermined compression.

7. A device for making a reinforced propellant grain comprising;

a rotatable grain forming core,

feeding means for feeding uncured grain material into the core as it is rotating,

said feeding means comprising an assembly of plural grain extruders having extrusion nozzles whose combined lengths constitute the end to end length of the grain being formed, said extrusion nozzle being inclined towards the core and disposed in abutting relationship constituting a discontinuous narrow slit, the slit being sufficiently spaced from the core so that a continuous ribbon of uncured grain can be deposited onto the core,

winding means for winding reinforcing filaments onto the grain as it is being formed, and

compacting means for compacting the uncured grain to make it of substantially uniform thickness.

8. The device according to claim 7 wherein the longitudinal axes of the individual extruders are inclined in the order of from 0° to 15° relative to a radial line of the core passing through the area of the core where the uncured grain material is being deposited, the inclination being sufficient to achieve optimum adherence.

9. A device for making a reinforced propellant grain comprising;

a rotatable grain-forming core,

feeding means for feeding uncured grain material onto the core as it is rotating, the feeding means having an elongated narrow extrusion slit whose length is equal to the length of the grain to be formed,

winding means for winding reinforcing filaments onto the grain as it is being formed,

compacting means for compacting the uncured grain to make it of substantially uniform thickness, and

linking means interconnecting the compacting means and feeding means for simultaneously adjusting the compacting means and feeding means between retracted positions and operative positions adjacent the core.

10. The device according to claim 15 wherein the linking means is a pulley system having a cord fixed at its opposite ends and looped at intermediate portions over idler pulleys fixed to the compacting means and to the extruder assembly.

11. A device for making a reinforced grain comprising;

a rotatable grain-forming core,

a plurality of grain extruders for feeding uncured grain material onto the core as it is rotating, the extruders having nozzles whose combined lengths constitute the end-to-end length of the grain to be formed, the nozzles further being inclined toward the core and disposed in abutting relationship to constitute an elongated narrow slit through which a ribbon of uncured grain is extruded onto the core,

winding means for winding reinforcing filaments onto the grain as it is being formed,

at least one compacting blade whose length is at least as long as the longitudinal length of the grain to be formed, the blade being heatable to lower the viscosity of the uncured grain material so as to make it more amenable to shaping.

12. The device according to claim 11 further comprising linking means interconnecting the compactor blade and the extruders for simultaneously adjusting them between respective retracting positions and operative positions adjacent the core.

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