CLAIMS

What is claimed is:

1. A method of manufacturing a multi-layered propellant grain comprising the following steps:

   providing a first formulation; said first formulation being in the range of viscosity similar to common propellant dough;

   providing a die configured to shape a structure having an outer shell and a hollow interior when material is extruded therethrough;

   extruding the first propellant formulation through said die, to produce a first propellant layer having an outer shell defining a hollow interior in the form of a passageway having open ends;

   providing a second propellant formulation; wherein the second formulation composition is close to a gel, a liquid or a paste, said second propellant formulation viscosity being at least fifty times less viscous than the first formulation;

   injecting said second propellant formulation into said passageway defined by said first propellant layer to form a second propellant layer disposed in said passageway, wherein the said injecting of said second propellant formulation is performed at substantially the same time as the said extruding of said first propellant formulation and;

   hardening or curing of the said second propellant layer.

   wherein the first and second propellant layers have different rates of burning.

2. The method according to claim 1 wherein the viscosity of the said second propellant formulation is in the range of about 0 to about 2000 pascal·seconds.

3. The method according to claim 1 wherein the first propellant layer is shaped as tube.

4. The method according to claim 3 wherein the propellant grain produced is composed of two concentric cylinders.

5. The method according to claim 1 wherein the first propellant layer is a slow burning layer composed of about 55% nitrocellulose and about 45% trimethylolethane trinitrate (TMETN).

6. The method according to claim 1 wherein the second propellant layer is a fast burning layer composed of about 26% GAP, about 39%TMETN and about 35% RDX.

7. The method according to claim 1 wherein the step of extruding the first propellant formulation through said die is carried out with a ram press or a screw extruder.

8. The method according to claim 1 wherein the step of injecting said second propellant formulation into said passageway is carried out through pressure differential.

9. The method according to claim 1 comprising the steps of softening said second propellant formulation with a solvent before injecting said second propellant formulation into said passageway and removing said solvent by evaporation after said second propellant formulation into said passageway in order to harden said second propellant layer.

10. The method according to claim 1 comprising the steps of heating said second propellant formulation before injecting said second propellant formulation into said passageway and cooling after said second propellant formulation after injecting said second propellant formulation in order to harden said second propellant layer.

11. The method according to claim 1 wherein the step of hardening said second propellant layer is carried out by heating said second propellant layer.

12. The method according to claim 1 wherein the step of hardening said second propellant layer is carried out by adding a hardening agent to the second propellant layer.

13. The method according to claim 1 wherein the steps of extruding the first propellant formulation and injecting said second propellant formulation into said channel are carried out simultaneously.

14. The method according to claim 1 wherein the first propellant layer has a rate of burning of about 0.1 to about 0.3 meters per second at 200MPa..

15. The method according to claim 1 wherein the second propellant layer has a rate of burning of about 0.15 to about 1 meter per second at 200MPa.

16. The method according to claim 1 wherein the extrusion step is carried out by inserting the first propellant formulation in a ram press extruder pressure of the ram press to force the first propellant formulation through said die.

17. The method according to claim 1 wherein the injection step is carried out by applying pneumatic air pressure to said second propellant formulation.

18. The method according to claim 1 wherein the die comprises first and second die members, the first die member being receivable in the second die member, the first die member defining a first channel formed therethrough for receiving the first propellant formulation, the first die member further including a tube separate from said passageway for receiving said second propellant formulation, the second die member defining a second channel for receiving the first propellant formulation delivered through said first channel and for receiving said tube, said second die member defining a terminal opening for delivering the first propellant formulation from the passageway and the second propellant formulation from the tube wherein the second propellant formulation is injected into the passageway defined by said first propellant layer.

CLAIMS

1. A method of manufacturing a multi-layered propellant grain comprising the following steps:

providing a first propellant formulation;

providing a die configured to provide a structure having an outer shell and a hollow interior when material is extruded therethrough;

extruding the first propellant formulation through said die, to produce a first propellant layer having an outer shell defining a hollow interior in the form of a passageway having open ends;

providing a second propellant formulation, said second propellant formulation being of low viscosity, wherein said second propellant formulation is of low viscosity such that it has an as-extruded viscosity of from 0 to 2000 pascal·seconds, and wherein an as-extruded viscosity of the first propellant formulation exceeds said low viscosity;

injecting said second propellant formulation into said passageway defined by said first propellant layer to form a second propellant layer disposed in said passageway, wherein the second propellant formulation has said low viscosity immediately following injection into said passageway, wherein the said injecting of said second propellant formulation is performed at the same time as the said extruding of said first propellant formulation; and

after the step of injecting, hardening said second propellant layer such that said second propellant layer achieves a viscosity that is greater than said low viscosity, said greater viscosity being sufficient to prevent flowing of the second propellant layer within said passageway,

wherein the first and second propellant layers have different rates of burning.

2. The method according to claim 1 wherein the first propellant layer is shaped as tube.

3. The method according to claim 2 wherein the propellant grain produced is composed of two concentric cylinders.

4. The method according to claim 1 wherein the first propellant layer is a slow burning layer composed of nitrocellulose and trimethylolethane trinitrate (TMETN).

5. The method according to claim 1 wherein the second propellant layer is a fast burning layer composed of glycidyl azide polymer (GAP), trimethylolethane trinitrate (TMETN) and cyclotrimethylene trinitramine (RDX).

6. The method according to claim 1 wherein the step of extruding the first propellant formulation through said die is carried out with a ram press or a screw extruder.

7. The method according to claim 1 wherein the step of injecting said second propellant formulation into said passageway is carried out through pressure differential.

8. The method according to claim 1 comprising the steps of softening said second propellant formulation with a solvent before injecting said second propellant formulation into said passageway and removing said solvent by evaporation after said second propellant formulation into said passageway in order to harden said second propellant layer.

9. The method according to claim 1 comprising the steps of heating said second propellant formulation before injecting said second propellant formulation into said passageway and cooling after said second propellant formulation after injecting said second propellant formulation in order to harden said second propellant layer.

10. The method according to claim 1 wherein the step of hardening said second propellant layer is carried out by heating said second propellant layer.

11. The method according to claim 1 wherein the step of hardening said second propellant layer is carried out by adding a hardening agent to the second propellant layer.

12. The method according to claim 1 wherein the first propellant layer has a rate of burning of about 0.1 to about 0.3 meters per second at 200MPa.

13. The method according to claim 1 wherein the second propellant layer has a rate of burning of about 0.15 to about 1 meter per second at 200MPa.

14. The method according to claim 1 wherein the extrusion step is carried out by inserting the first propellant formulation in a ram press extruder and pressure is applied to the ram press to force the first propellant formulation through said die.

15. The method according to claim 1 wherein the injection step is carried out by applying pneumatic air pressure to said second propellant formulation.

16. The method according to claim 1 wherein the steps of extruding and injecting are performed simultaneously using a die that comprises first and second die members, the first die member being receivable in the second die member, the first die member defining a first channel formed therethrough that receives the first propellant formulation for the extruding step, the first die member further including a tube separate from said first channel that receives said second propellant formulation for the injecting step, the second die member defining a second channel for receiving the first propellant formulation delivered through said first channel and for receiving said tube, said second die member defining a terminal opening for delivering the first propellant formulation from the first channel and the second propellant formulation from the tube, wherein the outer shell defining the hollow interior is formed as the first propellant formulation passes through the terminal opening and the second propellant formulation passes through the tube and into the passageway defined by said first propellant layer, wherein the second propellant formulation is thereby injected into the passageway defined by said first propellant layer.

17. The method of claim 1, wherein said second propellant formulation is of low viscosity such that it has an as-extruded viscosity of from 0 to 500 pascal·seconds.

18. The method of claim 1, wherein said second propellant formulation is of low viscosity such that it has an as-extruded viscosity of from 0.1 to 200 pascal·seconds.

19. The method of claim 1, wherein said second propellant formulation is of low viscosity such that it has an as-extruded viscosity of from 5 to 50 pascal·seconds.