MECHANICALLY GASSED EMULSION EXPLOSIVES AND RELATED METHODS AND SYSTEMS

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 63/364,014, titled MECHANICALLY GASSED EMULSION EXPLOSIVES AND RELATED METHODS AND SYSTEMS, filed May 2, 2022, and to U.S. Provisional Patent Application No. 63/237,079, titled MECHANICALLY GASSED EMULSION EXPLOSIVES AND RELATED METHODS, filed August 25, 2021, each of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates generally to the field of explosive compositions. More particularly, the present disclosure relates to mechanically gassed emulsion explosives and methods related thereto.

SUMMARY OF INVENTION

[0002a] According to a first aspect of the present invention, there is provided a method of delivering an emulsion explosive, the method comprising:

dividing an oxidizer salt solution into a first portion and a second portion;

atomizing a fuel with a gas to form an atomized fuel, wherein the fuel is substantially devoid of a bubble stabilizing agent;

mixing the first portion of the oxidizer salt solution with the atomized fuel to form a fuel-rich emulsion explosive having bubbles of the gas dispersed therein, and having an initial viscosity;

mixing the fuel-rich emulsion explosive with the second portion of the oxidizer salt solution to form a more balanced emulsion explosive having an increased viscosity;

homogenizing the more balanced emulsion explosive to form a homogenized emulsion explosive having a further increased viscosity.

[0002b] According to a second aspect of the present invention, there is provided an assembly for producing an atomized fuel stream, comprising:

an inlet configured to receive a mixture of fuel and compressed gas;

one or more atomizer nozzles each having an orifice, wherein each atomizer nozzle is situated to receive the mixture and is configured so that the mixture is atomized upon passing through the atomizer nozzle and exiting the orifice, thereby producing an atomized fuel stream; and

an outlet configured to receive the atomized fuel stream and direct the atomized fuel stream out of the assembly.

[0002c] According to a third aspect of the present invention, there is provided a method of delivering an emulsion explosive, the method comprising:

inserting a conduit into a borehole;

flowing an emulsion matrix through the conduit;

introducing a compressed gas into the emulsion matrix proximal an outlet of the conduit to form an emulsion explosive; and

conveying the emulsion explosive into the borehole.

[0002d] According to a fourth aspect of the present invention, there is provided a system for delivering an emulsion explosive, comprising:

a reservoir configured to store an emulsion matrix;

a gas supply configured to produce a compressed gas;

a conduit configured for insertion into a borehole, wherein the conduit is fluidically connected to the reservoir and configured to convey the emulsion matrix, and wherein the conduit is also fluidically connected to the gas supply and configured to convey the compressed gas to a point proximal to an outlet of the conduit and introduce the compressed gas into the emulsion matrix at said point to form an emulsion explosive; and

a nozzle located at and operably connected to the outlet of the conduit, wherein the nozzle is configured to convey the emulsion explosive to the borehole.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] To easily identify the discussion of any particular element or act, the most significant digit or digits in a reference number refer(s) to the figure number in which that element is first introduced.

[0004] FIG. 1 illustrates a process for delivering an emulsion explosive in accordance with one embodiment.

[0005] FIG. 2A is a cross-section view of an atomizer assembly for use in producing an atomized fuel stream according to an embodiment.

[0006] FIG. 2B is a cross-section of the view in FIG. 2A taken at the indicated transverse plane.

[0007] FIG. 2C is a cross-section view of a detail of the atomizer assembly of FIG. 2A.

[0008] FIG. 2D is an end view of a detail of FIG. 2C.

[0009] FIG. 2E is an end view of a detail of the atomizer assembly of FIG. 2A.

[0010] FIG. 2F is a side view of the detail of the atomizer assembly shown in FIG. 2E.

[0011] FIG. 2G is a cross-section view of another detail of the atomizer assembly of FIG. 2A.

[0012] FIG. 2H is an end view of a detail of FIG. 2G.

[0013] FIG. 3 is a cross-section view of a component of a system for delivering an emulsion explosive in accordance with an embodiment.

[0014] FIG. 4 illustrates a system for delivering an emulsion explosive in accordance with an embodiment.

DETAILED DESCRIPTION

[0015] This disclosure generally relates to water-in-oil (or melt-in-oil) emulsions for use as explosives, along with related methods. The term “water-in-oil” means a dispersion of droplets of an aqueous solution or water-miscible melt (the discontinuous phase) in an oil or water-immiscible organic substance (the continuous phase). The water-in-oil emulsion explosives of this invention contain a water-immiscible organic fuel as the continuous phase and an emulsified inorganic oxidizer salt solution or melt as the discontinuous phase. (The terms “solution” or “melt” hereafter shall be used interchangeably.)

CLAIMS

1. A method of delivering an emulsion explosive, the method comprising:

dividing an oxidizer salt solution into a first portion and a second portion;

atomizing a fuel with a gas to form an atomized fuel, wherein the fuel is substantially devoid of a bubble stabilizing agent;

mixing the first portion of the oxidizer salt solution with the atomized fuel to form a fuel-rich emulsion explosive having bubbles of the gas dispersed therein, and having an initial viscosity;

mixing the fuel-rich emulsion explosive with the second portion of the oxidizer salt solution to form a more balanced emulsion explosive having an increased viscosity;

homogenizing the more balanced emulsion explosive to form a homogenized emulsion explosive having a further increased viscosity.

2. The method of claim 1, wherein the initial viscosity of the fuel-rich emulsion explosive is of about 20 Pa·s or less, or about 8 Pa·s to about 14 Pa·s.

3. The method of claim 1 or claim 2, wherein the increased viscosity of the more balanced emulsion explosive is about 6 Pa·s to about 20 Pa·s greater than the viscosity of the fuel-rich emulsion explosive, and/or wherein the more balanced emulsion explosive has a viscosity of about 20 Pa·s to about 35 Pa·s.

4. The method of any one of claims 1 to 3, wherein the viscosity of the homogenized emulsion explosive is increased by about 40 Pa·s to about 180 Pa·s relative to the more balanced emulsion explosive, and/or wherein the viscosity of the homogenized emulsion explosive is about 80 Pa·s to about 300 Pa·s.

5. The method of any one of claims 1 to 4, wherein the bubbles have a median bubble size of about 0.5 μm to about 250 μm, or about 20 μm to about 100 μm.

6. The method of any one of claims 1 to 5, wherein the second portion of the oxidizer salt solution is about 45% to about 80% of the total amount of the oxidizer salt solution on a weight-per-weight basis, or about 55% to 65% of the total oxidizer salt solution.

7. The method of any one of claims 1 to 6, wherein the fuel further comprises up to 25 wt% of an emulsifier, a homogenizing agent, or combination thereof.

8. The method of claim 7, wherein the emulsifier, homogenizing agent, or combination thereof comprises about 20 wt% to about 100 wt% homogenizing agent.

9. The method of any one of claims 1 to 8, further comprising flowing the homogenized emulsion explosive through a conduit into a borehole.

10. The method of claim 9, further comprising introducing a stream of the gas into the homogenized emulsion explosive proximal to an outlet of the conduit.

11. The method of any one of claims 1 to 10, further comprising pressurizing the second portion of the oxidizer salt solution to provide at least a portion of the pressure necessary to homogenize the more balanced emulsion explosive.

12. An assembly for producing an atomized fuel stream, comprising:

an inlet configured to receive a mixture of fuel and compressed gas;

one or more atomizer nozzles each having an orifice, wherein each atomizer nozzle is situated to receive the mixture and is configured so that the mixture is atomized upon passing through the atomizer nozzle and exiting the orifice, thereby producing an atomized fuel stream; and

an outlet configured to receive the atomized fuel stream and direct the atomized fuel stream out of the assembly.

13. The assembly of claim 12, comprising 1 to 13 atomizer nozzles, or 3 to 7 atomizer nozzles.

14. The assembly of claim 12 or claim 13, wherein the orifice has a diameter of about 0.03125 inches to about 0.15625 inches, or about 0.0625 inches to about 0.1250 inches.

15. A method of delivering an emulsion explosive, the method comprising:

inserting a conduit into a borehole;

flowing an emulsion matrix through the conduit;

introducing a compressed gas into the emulsion matrix proximal an outlet of the conduit to form an emulsion explosive; and

conveying the emulsion explosive into the borehole.

16. The method of claim 15, wherein the emulsion matrix is a homogenized emulsion explosive.

17. The method of claim 15 or 16, further comprising mixing the emulsion matrix with the compressed gas proximal the outlet of the conduit, and/or flowing the emulsion matrix and the compressed gas through the conduit in separate streams.

18. A system for delivering an emulsion explosive, comprising:

a reservoir configured to store an emulsion matrix;

a gas supply configured to produce a compressed gas;

a conduit configured for insertion into a borehole, wherein the conduit is fluidically connected to the reservoir and configured to convey the emulsion matrix, and wherein the conduit is also fluidically connected to the gas supply and configured to convey the compressed gas to a point proximal to an outlet of the conduit and introduce the compressed gas into the emulsion matrix at said point to form an emulsion explosive; and

a nozzle located at and operably connected to the outlet of the conduit, wherein the nozzle is configured to convey the emulsion explosive to the borehole.

19. The system of claim 18, wherein the nozzle comprises at least one port configured for introducing the gas into the emulsion matrix at the point proximal to the outlet.

20. The system of claim 18 or 19, further comprising a mixer located proximal to the outlet of the conduit, wherein the mixer is configured to mix the emulsion matrix with the compressed gas.

21. The system of claim 20, wherein the mixer is incorporated into the nozzle.

22. The system of any one of claims 18 to 21, further comprising a homogenizer located proximal the outlet of the conduit.

23. The system of claim 22, wherein the homogenizer is incorporated into the nozzle.

24. The system of any one of claims 18 to 23, wherein the conduit comprises a flexible tube, wherein the flexible tube comprises a first annulus comprising an inner surface and an outer surface, wherein the inner surface is separated from the outer surface by a first thickness, wherein

the first annulus is fluidically connected to the reservoir and is configured to convey the emulsion matrix to the point proximal to the outlet.

25. The system of claim 24, wherein the conduit further comprises a second annulus coextensive to the first annulus, wherein the second annulus is fluidically connected to the gas supply and is configured to convey the compressed gas to the point proximal to the outlet.

26. The system of claim 25, wherein the second annulus is radially located between the inner surface and the outer surface of the first annulus, or the second annulus is radially located within the inner surface of the first annulus, or the second annulus defines a separate tube situated outside the outer surface of the first annulus.

27. The system of claim 25 or claim 26, wherein the second annulus forms a substantially spiral path around the first annulus.

28. The system of any one of claims 18 to 27, wherein the reservoir is a homogenizer, and/or the reservoir can be loaded with the emulsion matrix after preparation of said emulsion matrix.