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(54) **PERFORATOR CHARGE WITH A CASE CONTAINING A REACTIVE MATERIAL**

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(57) **ABSTRACT**

A perforator charge includes a case formed of a material blend that includes a reactive material that is activated during explosive detonation of the perforator charge. An explosive and a liner are contained in the case, with the liner to collapse in response to detonation of the explosive.

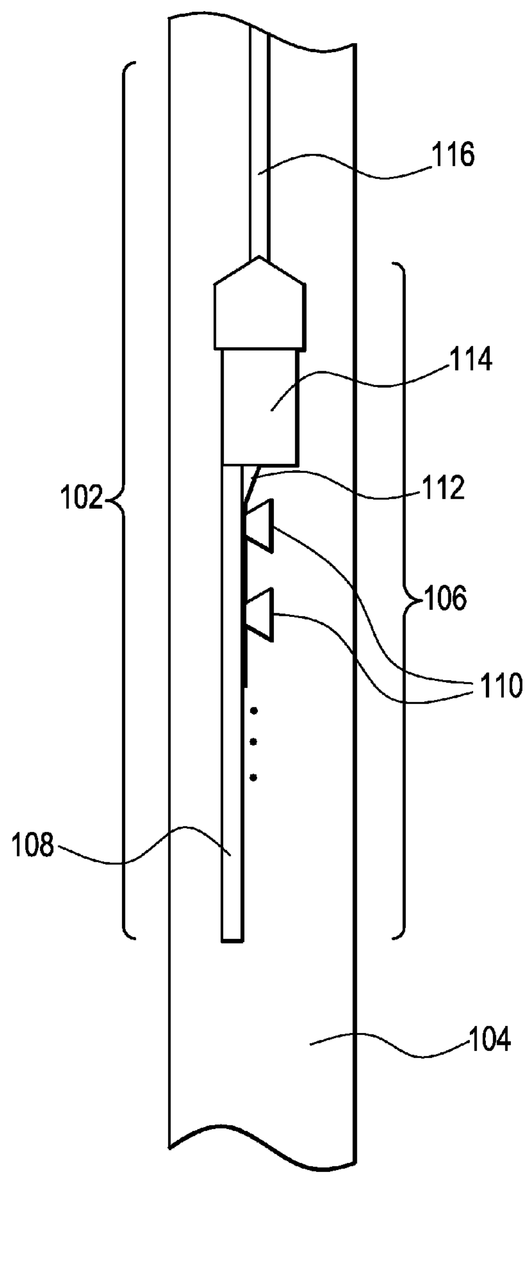


FIG. 1

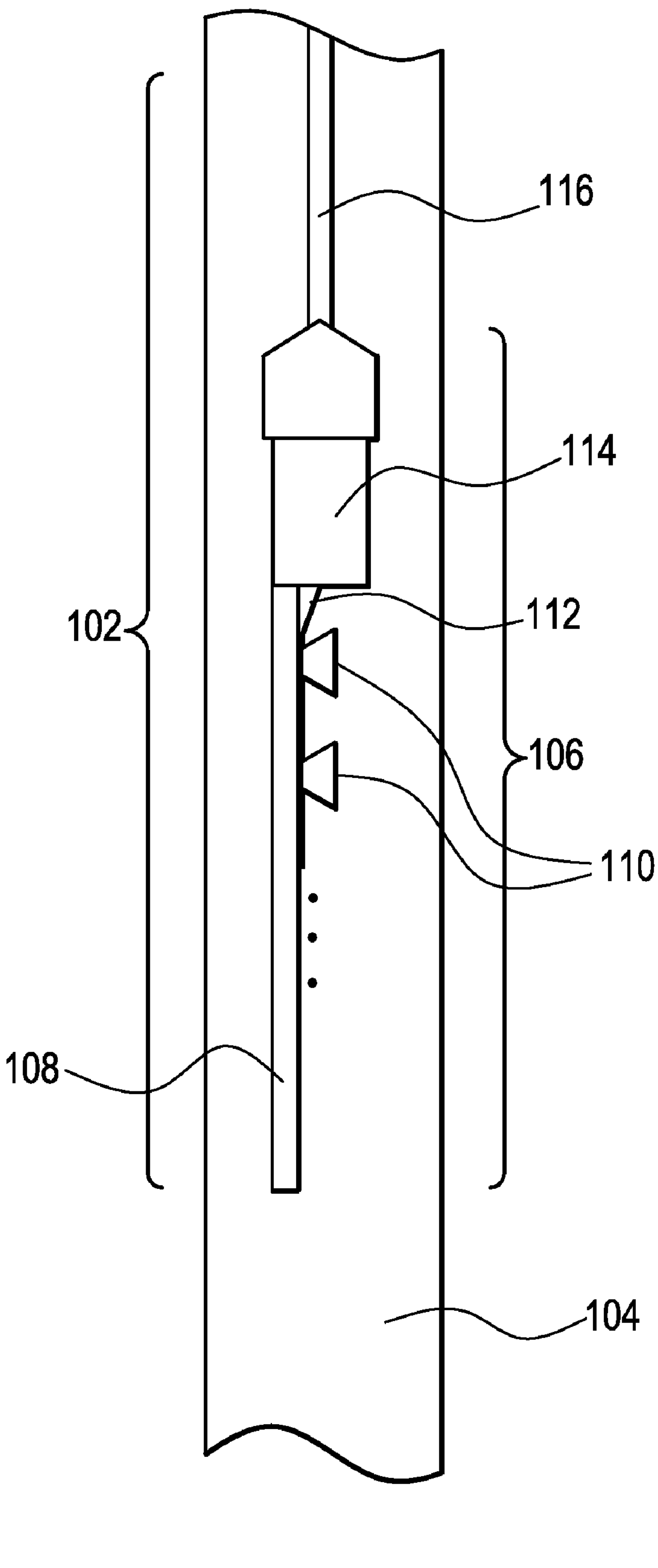


FIG. 2

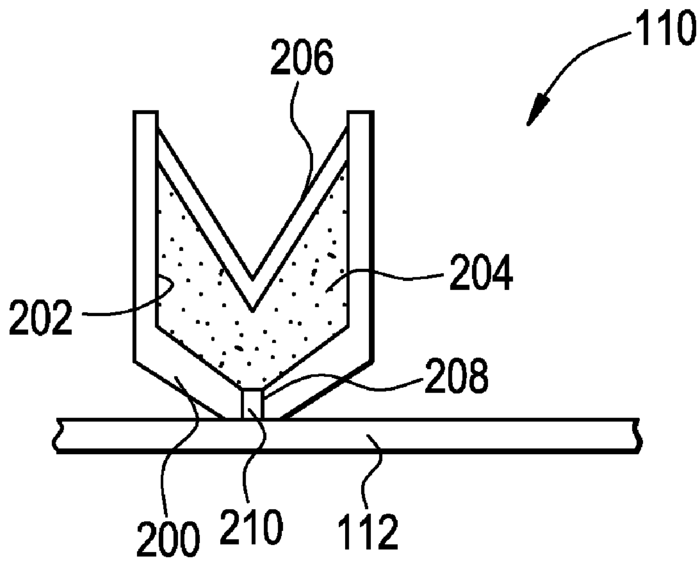
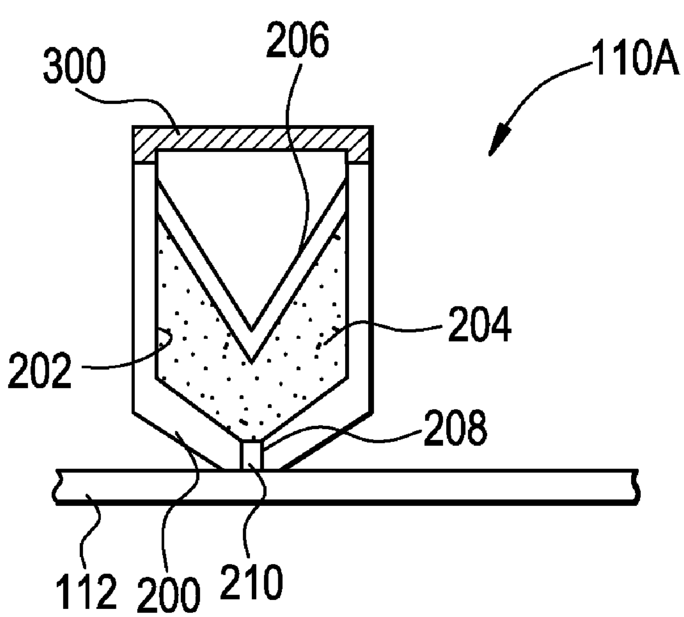

110
206
204
202
208
200
210
112

FIG. 3


300
206
110A
204
202
208
112
200
210

PERFORATOR CHARGE WITH A CASE CONTAINING A REACTIVE MATERIAL

TECHNICAL FIELD

[0001] The invention relates generally to a perforator charge having a case including a reactive material.

BACKGROUND

[0002] To complete a well for purposes of producing fluids (such as hydrocarbons) from a reservoir, or to inject fluids into the reservoir, one or more zones in the well are perforated to allow for fluid communication between the wellbore and the reservoir. Normally, perforation is accomplished by lowering a perforating gun string that has one or more perforating guns to the desired intervals within the well. Activation of the one or more guns in the perforating gun string creates openings in any surrounding casing and extends perforations into the surrounding formation.

[0003] A perforating gun typically includes a gun carrier and a number of shaped charges mounted to the gun carrier. The gun carrier can be a sealed gun carrier that contains the shaped charges and that protects the shaped charges from the external wellbore environment. Alternatively, the gun carriers can be on a strip carrier onto which capsule shaped charges are mounted. A capsule shaped charge is a shaped charge whose internal components are sealably protected against the wellbore environment.

[0004] The explosive nature of the formation of perforation tunnels shatters sand grains of the formation. A layer of "shock damaged region" having a permeability lower than that of the virgin formation matrix may be formed around each perforation tunnel. The process of forming perforation tunnels may also produce a tunnel full of debris mixed with shaped charge debris. The extent of damage and the amount of loose debris in the tunnels, may impair the productivity of production wells or the injectivity of injector wells.

[0005] Various approaches have been proposed to address damage and the issue of debris associated with forming perforations using perforating guns. However, it is desirable for additional solutions that are not offered by conventional techniques.

SUMMARY

[0006] In general, according to an embodiment, a perforator charge includes a case formed of a material blend that includes a reactive material that is activated during explosive detonation of the perforator charge. The reactive material of the case of the perforator charge when activated can provide for various beneficial effects, according to some embodiments. For example, a pressure pulse may be created in a wellbore interval as a result of the activation of the reactive material.

[0007] Other or alternative features will become apparent from the following description, from the drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** illustrates an example tool string having a perforating gun with perforator charges according to some embodiments.

[0009] FIG. **2** illustrates a non-capsule perforator charge according to an embodiment.

[0010] FIG. **3** illustrates a capsule perforator charge according to another embodiment.

DETAILED DESCRIPTION

[0011] In the following description, numerous details are set forth to provide an understanding of the present invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiments are possible.

[0012] As used here, the terms "above" and "below"; "up" and "down"; "upper" and "lower"; "upwardly" and "downwardly"; and other like terms indicating relative positions above or below a given point or element are used in this description to more clearly describe some embodiments of the invention. However, when applied to equipment and methods for use in wells that are deviated or horizontal, such terms may refer to a left to right, right to left, or diagonal relationship as appropriate.

[0013] FIG. **1** illustrates a tool string **102** that has been deployed in a wellbore **104**, where the tool string includes a perforating gun **106** that has a carrier **108** to which are mounted various perforator charges **110** (e.g., shaped charges or other explosive devices that form perforating jets) according to some embodiments. The carrier **108** can be an expendable carrier that is designed to shatter as a result of detonation of the perforator charges **110**. An example of such an expendable carrier is a strip carrier, such as a carrier formed of a metal strip. In a different implementation, instead of mounting the perforator charges **110** on a strip carrier, the carrier can be a seated housing that has an inner chamber in which the perforator charges are located, with the chamber being sealed against external wellbore fluids in the wellbore **104**.

[0014] As depicted in FIG. **1**, when the perforator charges **110** are mounted to the carrier strip **108** such that the perforator charges **110** are exposed to wellbore fluids, the perforator charges **110** are capsule perforator charges that have a capsule to provide a fluid seal to protect internal components of the perforator charges **110** against the wellbore fluids. Alternatively, if the perforator charges **110** are provided in a sealed chamber of a carrier housing, in a different implementation, then the perforator charges can be non-capsule perforator charges.

[0015] The perforator charges **110** in the example of FIG. **1** are ballistically connected to a detonating cord **112**. The detonating cord **112** is connected to a firing head **114**. When activated, the firing head **114** initiates the detonating cord **112**, which in turn causes detonation of the perforator charges **110**.

[0016] In a different implementation, the detonating cord **112** can be replaced with one or more electrical wires connecting the firing head **114** to the perforator charges. Electrical signal(s) can be sent by the firing head **114** over the one or more electrical wires to activate the perforator charges. For example, the perforator charges can be associated with electrically-activated initiators (e.g., electrical foil initiators or EFIs), which when activated by an electrical signal causes initiation of a detonator or explosive to detonate the corresponding perforator charge.

[0017] The perforating gun **106** is carried by a carrier line **116**, which can be a wireline, slickline, coiled tubing, production tubing, and so forth. In accordance with some embodiments, each perforator charge **110** has an outer case that is formed of a material blend that includes a reactive material. A reactive material refers to a material that reacts with detonation gases, wellbore fluids, and/or with another reactive material during explosive detonation of the perforator charge. Reaction of the reactive material in the outer case of the perforator charge can produce a pressure pulse that can last for some amount of time longer (e.g., one or two orders of magnitude longer) than the explosive detonation of the perforator charge.

[0018] In some embodiments, the material blend of the case of the perforator charge can be a powdered material that includes the reactive material as well as a non-reactive material that provides for enhanced density and strength of the case. In a different embodiment, the material blend of the outer case can be a solid, rather than a powdered, material blend.

[0019] The pressure pulse generated as a result of activation of the reactive material during perforator charge detonation can produce a dynamic overbalance condition in a particular wellbore interval (the interval in which the perforator charge or perforating gun is located), which is a pressure condition in which the particular wellbore interval achieves a higher pressure than the pressure of a surrounding reservoir (or at least the near-wellbore region of the surrounding reservoir). Creating a dynamic overbalance condition in a wellbore interval has several potential applications, including injecting one or more target fluids into perforation tunnels, producing a transient overbalance condition, fracturing perforation tunnels, and so forth.

[0020] In some examples, the one or more target fluids that can be injected into perforation tunnels include a treating fluid such as a consolidation fluid that can be used to strengthen perforation tunnels and near-wellbore regions of the reservoir to prevent formation movement or movement of fine particles. One example type of consolidation fluid includes an epoxy fluid that is embedded with micro-capsules, where the micro-capsules have inner cavities that contain a hardener or catalyst fluid. A different type of treating fluid can be a post-wash fluid. Another type of treating fluid can be acid, such as HCl to treat a carbonate reservoir. Acidizing helps remove or reduce perforation damage. Yet another type of treating fluid can be proppant-laden fracturing fluid, where the proppant includes particles mixed with fracturing fluid, which can be used in a fracturing operation to hold fractures open.

[0021] FIG. **2** shows an example perforator charge **110** that has an outer case **200**. The outer case **200** defines an inner chamber **202** to receive a main explosive **204**. Also, a liner **206** is provided inside the outer case **202**, where the liner **206** generally has a generally conical shape. The conical shape of the liner **206** provides for a deeper perforation hole. Alternatively, the liner **206** can have a different shape, such as a general bowl shape, which would allow for creation of larger holes. The main explosive **204** is provided between the liner **206** and the inside of the outer case **200**.

[0022] In some embodiments, the outer case **200** can be formed of a powered material, using a compaction technique, where the powdered material includes both a non-reactive material for density and green strength (which refers to the ability of the case to undergo handling without distortion), and a reactive material that is activated by detonation gases, wellbore fluids, and/or with another reactive material during detonation of the perforator charge.

[0023] The compaction technique used to form the outer case **200** involves mixing the non-reactive and reactive material and applying compaction to the mixture to form the case **200**. In other implementations, other manufacturing techniques can be used to make the outer case **200**, such as an injection molding technique or other technique.

[0024] A reactive material can include just a single material or a combination of multiple reactive materials. Examples of the reactive material that can be used in the case **200** include titanium (Ti), nickel-aluminum (Ni—Al), a titanium alloy (e.g., titanium iron, titanium silicon, titanium nickel, titanium aluminum, titanium copper, etc.), a titanium powder mixed with other metal powder (e.g., magnesium, tungsten, copper, lead, tin, zinc, gold, silver, steel, tantalum, etc.), a titanium alloy powder mixed with other metal powder, and any other reactive materials. Examples of non-reactive materials include tungsten, copper, lead, bismuth, tin, and so forth.

[0025] To increase the green strength of the powdered material case **200**, a high-temperature epoxy coating can be applied to the external surface of the case **200**, or alternatively, the case **200** can be impregnated with a high-temperature epoxy. The epoxy can also contain a fuel and/or an oxidizer in some implementations to aid in disintegration of the case **200**.

[0026] As further depicted in FIG. **2**, an opening **208** at the rear of the case **200** allows for an explosive material portion **210** to be provided, where the explosive material portion **210** is ballistically coupled to the detonating cord **112** to allow for initiation in the detonating cord **112** to cause the explosive material portion **210** to detonate, which in turn causes the main explosive **204** to detonate. Detonation of the main explosive **204** causes the liner **206** to collapse such that a perforating jet is formed, where the perforating jet extends away from the perforator charge **110**. The perforating jet is directed towards the structure (e.g., casing and/or surrounding formation) in which a corresponding perforation tunnel is to be formed.

[0027] During detonation of the main explosive **204**, the reactive material inside the outer case **200** reacts with the detonation environment such that the reactive material is activated to generate heat or gas that increases pressure. As a result, a pressure pulse can be produced from reaction or activation of the reactive material, where the pressure pulse lasts longer than the explosive detonation of the perforator charge **110**.

[0028] As noted above, the pressure pulse produces a dynamic overbalance condition in a wellbore interval, where the dynamic overbalance condition can be used for various purposes, including fluid injection, transient overbalance creation, and fracturing, as examples.

[0029] FIG. **3** shows an alternative embodiment of a perforator charge, identified as **110**A. The perforator charge **110**A is identical in construction with the perforator charge **110** of FIG. **2**, except that a cap **300** is also provided in the perforator charge **110**A to sealably engage with the outer case **200**, where the cap **300** allows for the internal components of the perforator charge (liner and explosive material to be protected from the external wellbore environment.

[0030] Effectively, the cap **300** and outer case **200** form a capsule that sealably defines a sealed inner chamber containing the internal components of the perforator charge. The perforator charge **110**A is a capsule perforator charge, whereas the perforator charge **110** of FIG. **2** is a non-capsule perforator charge.

[0031] A further benefit of using an outer casing (particularly one formed of a powdered material) that includes a reactive material is that activation of the reactive material helps to further reduce debris associated with the perforator charge. Activation of the reactive material helps to further disintegrate the outer casing.

[0032] While the invention has been disclosed with respect to a limited number of embodiments, those skilled in the art, having the benefit of this disclosure, will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover such modifications and variations as fall within the true spirit and scope of the invention.

What is claimed is:

1. A perforator charge comprising:

a case formed of a material blend that includes a reactive material that is activated during explosive detonation of the perforator charge;

an explosive contained in the case; and

a liner contained ill the case, the liner to collapse in response to detonation of the explosive.

2. The perforator charge of claim **1**, wherein the reactive material when activated during explosive detonation of the perforator charge produces a pressure pulse in a wellbore interval.

3. The perforator charge of claim **2**, wherein the reactive material when activated produces a dynamic overbalance condition.

4. The perforator charge of claim **1**, wherein the reactive material is activated by at least one selected from the following: a detonation gas, a wellbore fluid, and another reactive material.

5. The perforator charge of claim **1**, wherein the reactive material comprises a powdered reactive material.

6. The perforator charge of claim **1**, wherein the reactive material is at least one material selected from the following: titanium, a titanium alloy, titanium mixed with another metal, a titanium alloy mixed with another metal, and nickel aluminum.

7. The perforator charge of claim **1**, wherein the material blend of the case further comprises a non-reactive material mixed with the reactive material.

8. The perforator charge of claim **7**, wherein the non-reactive material is selected from the following: tungsten, copper, tin, lead, and bismuth.

9. The perforator charge of claim **7**, wherein the non-reactive material provides enhanced density and strength for the case.

10. The perforator charge of claim **7**, wherein the non-reactive material and reactive material are compacted to form the case.

11. The perforator charge of claim **1**, wherein the material blend comprises a powdered material blend.

12. A perforating gun comprising:

a carrier; and

at least one perforator charge mounted to the carrier, wherein the at least one perforator charge comprises:

a case formed of a material blend that includes a reactive material that is activated in an explosive detonation environment generated by the perforator charge;

an explosive contained in the case; and

a liner contained in the case, the liner to collapse in response to detonation of the explosive.

13. The perforating gun of claim **12**, wherein the material blend further comprises a non-reactive material mixed with the reactive material, the non-reactive material to provide density and green strength.

14. The perforating gun of claim **12**, wherein the at least one perforator charge comprises at least one capsule perforator charge.

15. The perforating gun of claim **12**, wherein the at least one perforator charge comprises at least one non-capsule perforator charge.

16. The perforating gun of claim **12**, wherein the carrier comprises a carrier strip.

17. The perforating gun of claim **12**, wherein the reactive material is activated by at least one selected from the following: detonation gases and a wellbore fluid.

18. The perforating gun of claim **12**, wherein the reactive material comprises at least one material selected from the following: titanium, a titanium alloy, titanium mixed with another metal, a titanium alloy mixed with another metal, and nickel aluminum.

19. A method for use in a wellbore, comprising:

lowering a perforating tool into the wellbore, wherein the perforating tool comprises at least one perforator charge including a case that contains an explosive, wherein the case is formed of a material blend including a reactive material; and

activating the at least one perforator charge, wherein the reactive material of the at least one perforator charge is activated during detonation of the at least one perforator charge to create a corresponding pressure pulse.

20. The method of claim **19**, wherein the pressure pulse causes generation of a dynamic overbalance condition in an interval of the wellbore.

21. The method of claim **20**, further comprising:

performing at least one of the following in presence of the dynamic overbalance condition: fluid injection, transient overbalance generation, and fracturing.

22. The method of claim **19**, wherein the reactive material comprises at least one material selected from the following: titanium, a titanium alloy, titanium mixed with another metal, a titanium alloy mixed with another metal, and nickel aluminum.

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