

AN EXPANDABLE METAL SEALANT WELLBORE CASING PATCH

BACKGROUND

[0001] In downhole wellbore environments, well casing can be damaged, e.g. during well development and during production due to corrosion and erosion or perforations in a well casing that were perforated in a wrong location or perforations in well location that is no longer needed or desirable for production. As such, there is a need to patch damaged well casing in downhole well environments. Casing patches are commonly used in the well services industry to repair damaged casing. Casing patches currently in use utilize blank pipes, i.e. or deformable metal pipes or plastic pipes, which requires sophisticated expansion techniques, and elastomers to achieve a seal. However, to create a case patch using the aforementioned materials is expensive and requires the downhole casing to be in good condition, which obviously defeats the purpose of needing a casing patch and, therefore, limits the application of these materials. Furthermore, due to the inadequacies of the aforementioned materials and conditions in downhole well environments the seal is unreliable, temporary, and can significantly reduce the Internal Diameter (ID) of production tubing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] For a more complete understanding of the features and advantages of the present disclosure, reference is now made to the detailed description along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0004] FIG. 1 is an illustration of a diagram of a well site where service operations are performed, in accordance with certain example embodiments;

[0005] FIGS. 2A-2C are illustrations of a positioned casing patch (2A), an anchored for hydrolysis reaction anchored patch (2B), and a hydrated casing patch (2C), respectively, in accordance with certain example embodiments;

[0006] FIG. 3A-3C is an illustration of a positioned casing patch (3A), an anchored for hydrolysis reaction casing patch (3B), and a hydrated casing patch (3C), respectively, in accordance with certain example embodiments;

[0007] FIG. 4 is an illustration of a well casing, metal sealant, and base, in accordance with example embodiments; and

[0008] FIG. 5 is an illustration of a metal sealant manufactured in a tubular shape and with a predetermined thickness, according to certain example embodiments.

DETAILED DESCRIPTION

[0009] While the making and using of various embodiments of the present disclosure are discussed in detail below, it should be appreciated that the present disclosure provides many applicable inventive concepts, which can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative and do not delimit the scope of the present disclosure. In the interest of clarity, not all features of an actual implementation may be described in the present disclosure. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming but would be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0010] Presented herein is a disclosure of a simpler, more reliable, less expensive, effective system, method, and apparatus for repairing damaged well casing in a downhole environment. Specifically, a metal sealant, expandable in response to chemical reaction, presented herein replaces traditional methods, such as elastomers and deformable metal, to repair damaged well casing. A casing patch can be created by placing a metal sealant over a tubular, i.e. mandrel, and ran downhole. Once in a desired location, the casing patch can be anchored by a means of weighting and/or a means of expansion, e.g. using splits and/or a packer. Once anchored, fluid can be pumped downhole causing the metal sealant to chemically react, to expand, and to create a pressure tight seal against the casing in the well. The seal acts as a pressure barrier as well as provides additional anchoring force for the tubular.

[0011] Referring now to Fig. 1, illustrated is a diagram of a well site where service operations are performed, in accordance with certain example embodiments, denoted generally as 10. The well site 10 includes a runner controller and pump 12, an oilfield tubular 14, a well head 16, well casing 18, wellbore 20, tool 22, casing patch 24, and perforations 26 formed in the well casing 18 and wellbore 20. The tool string 14 can be ran downhole to a particular location. For example, a reservoir accessible through the perforations 26 may no longer produce or may produce unwanted fluid, such as water. The tool 22 can be positioned in proximity within the ID of the well casing 18 and the casing patch 24 attached thereto used to seal the perforated section of the well casing 18. The casing patch 24 comprises a metal sealant. In an embodiment, the tool 22 can include a packer or packers with the packer(s) used to temporarily anchor the casing patch 24 by applying a predetermined amount of force to the casing patch 24. The predetermined amount of force can be defined as an amount of force necessary to expand the casing patch 24 so that an outer diameter of the casing patch 24 is equal to or approximately equal to the ID of the well casing 18. In another embodiment, the tool 22 can include slips configured to temporarily anchor the casing patch 24 in position by using the weight of the slips. In some embodiments, the casing patch 24 can be anchored at a location of the wellbore 20 by positioning the casing patch 24 approximate to a joint where the ID of the well casing 18 changes to an ID approximate to or equal to the casing patch 24. In some embodiments, elastomers and deformable metal pipes or plastics can be used to facility the anchoring process. Water-based wellbore fluids proximate the casing patch 24 cause the metal sealant to chemically react, to expand, and to harden. In cases where the wellbore has insufficient water-based wellbore fluids proximate the casing patch 24, then once the casing patch 24 is anchored, water or fluid carrying water can be pumped downhole

causing the metal sealant to expand and harden. The expanding metal expands into the damaged section of well casing 18 and coalesces with the damaged section of well casing 18.

[0012] Referring now to Figs. 2A-2C, illustrated are a positioned, an anchored for chemical reaction, and a reacted casing patch 24, respectively, according to certain example embodiments. In Fig. 2A, the setting tool 22 is configured to secure the casing patch 24. For example, the dimensions, in relation to the casing patch, of the tool 22 are such that the tool 22 and casing patch 24 create a secure coupling. The tool 22 includes a packer 22a. The casing patch 24 includes an elastomer 28, or alternatively a deformable metal or plastic, a metal sealant 30 having a predetermined thickness, and a base 32. Although, it should be understood that the elastomer is optional. However, the elastomer can be used to protect an undamaged section of well casing 18. The base 32 includes a first section having a dimension greater than a second section. The packer 22a can be activated from the runner controller 12 whereupon activation a predetermined amount of force is applied to the first section of the base 32 which acts to anchor the first section of the base 32 to the well casing 18, see Fig. 2B. At this point, H₂O can be pumped downhole from the pump 12 creating the chemical reaction with the metal sealant 30 causing the metal sealant 30 to expand and harden, see Fig. 2C. The setting tool 22 can be removed from the wellbore 20 at any time after setting of the patch.

[0013] It should be understood that the base 32 may not be necessary in all applications. In another option, the base 32 can be constructed from a degradable material, such as a degradable metal or a degradable polymer. The degradable material reacts at a slower rate than the expanding metal so that the metal expands and creates the seal before the degradable material degrades and loses structural support. For example, the expanding metal can form its seal at 2x the rate to 100x

the rate that the degradable material takes to degrade. Once the expanded metal has formed its seal, then the degradable supporting materials can degrade and allow for a greater flow area.

[0014] Referring now to Figs. 3A-3C, illustrated are a positioned, an anchored for chemical reaction, and an expanded casing patch 24, respectively, according to certain other example embodiments. In Fig. 3A, a series of packers 22a are used to position the casing patch 24 without necessarily anchoring the casing patch 24 to the well casing 18. However, the running tool 22 can be weighted and/or elsewhere anchored in the well casing 18 providing the casing patch 24 with the stability needed to react, expand, and seal. In Fig. 3B, splits 40 can be configured to secure the casing patch 24. For example, the dimensions, in relation to the casing patch 24, of the tool 22 are enough to secure the casing patch 24 to the tool 22. The sheer weight of the splits 40 can be enough to act as the stabilizer or anchor needed to react, expand, and seal the metal sealant 30. At this point, the water-based fluid can be pumped downhole from the pump 12 creating the chemical reaction with the metal sealant 30 causing the metal sealant 30 to expand and to harden, see Fig. 3C. Alternatively, the metal sealant 30 can react with the water-based fluid that is already existing within the wellbore. The tool 22 can be removed from the wellbore 20 at any time after the installation process, but preferably after the metal sealant has hardened.

[0015] As previously stated, the predetermined amount of force can be defined as an amount of force necessary to expand the casing patch 24, i.e. the first section, so that an outer diameter of the casing patch 24 is equal to or approximately equal to the ID of the well casing 18. The predetermined thickness of the metal sealant 30 can be determined by the diameter of the metal sealant 30 after expanding and hardening and the ID of the well casing 18. The metal sealant 30 should be designed in such a way that is affective at creating a seal without causing additional damage to the well casing 18. Obviously, the dimensions of the tool, the

predetermined amount of force, and the predetermined thickness are determined based on the ID of the well casing.

[0016] Referring now to Fig. 4, illustrated is a well casing 18, metal sealant 30, and base 32, according to certain example embodiments. In this embodiment, the metal sealant 30 is illustrated with the unreacted metal sealant 30A and reacted metal sealant 30B.

[0017] The compounds and reactions of the metal sealant can be defined by the following equation: Metal + water $\rightarrow$ Metal hydroxide + H₂ gas.

[0018] The metal hydroxide forms a hard cement-like barrier. The metal can be any metal that forms this reaction but is preferably magnesium, aluminum, calcium, or alloys that contain those metals. The chemical reactions for these preferred metals are defined by the following equations:



[0019] Equation 1 is a hydration reaction that uses magnesium metal, where Mg(OH)₂ is a hard cement-like barrier. Equation 2 is a hydration reaction that uses aluminum metal. Equation 3 is a hydration reaction that uses calcium metal, where Ca(OH)₂ is known as portlandite. The hydrated metals are considered to be relatively insoluble in water. The water-based chemical reaction of any metal can create a metal hydroxide. The metals described above are alkaline earth metal (Mg and Ca) or a transition metal (Al) used in the hydrolysis reaction. However, other alkaline or transition metals can be used.

[0020] In an embodiment, the material used in the hydrolysis reaction is a magnesium alloy. The alloy elements to the magnesium can be at least one selected from the group comprising Al, Zn, Mn, Zr, Y, Nd, Gd, Ag, Ca, Sn, and RE. In some embodiments, the alloy is further alloyed

with a dopant, such as Ni, Fe, Cu, Co, Ir, Au, and Pd, that accelerates the chemical reaction. In some embodiments, the alloy is alloyed with a dopant, such as Ga, Mg, that inhibits the formation of a passivation film that could limit the reaction. The metal alloy can be constructed in a solid solution process where the elements are combined with the molten metal or metal alloy. Alternatively, the metal alloy could be constructed with a powder metallurgy process. The metal can be heat treated with a precipitation process or a tempering process in order to change the size and distribution of the metal grains.

[0021] In some embodiments, the starting metal can be a metal oxide. For example, calcium oxide (CaO) with water produces calcium hydroxide in an energetic reaction. Due to the higher density of calcium oxide, this can have a 260% volumetric expansion where converting 1 mole of CaO goes from 9.5cc to 34.4cc of volume. In one variation, the metal sealant is formed in a serpentine reaction. Additional ions can be added to the reaction, including silicate, sulfate, aluminate, phosphate. The metal can be alloyed to increase the reactivity or to control the formation of oxides.

[0022] Referring now to Fig. 5, illustrated is a metal sealant 30 manufactured in a tubular shape and with a predetermined thickness, according to certain example embodiments. The metal sealant 30 can be manufactured to many different shapes with an adequate volume of material needed to create a proper seal in the certain settings. The shape can be a single long tube, multiple short tubes, ring or series of rings. The metal sealant 30 can be manufactured to have different sections, such as, alternating steel, expandable (swellable) rubber, and expandable metal rings. Coatings (such as paint or polymer) can be used to delay reactions. Additionally, non-expanding components can be added into the manufacturing process to create a metal sealant 30 with non-expanding components. For example, ceramic, elastomer, glass, or non-reacting metal components

can be embedded in the metal sealant 30 through the manufacturing process. Alternatively, or in addition thereto, non-expanding components can be coated on the surface of the metal sealant 30.

[0023] The above-disclosed embodiments have been presented for purposes of illustration and to enable one of ordinary skill in the art to practice the disclosure, but the disclosure is not intended to be exhaustive or limited to the forms disclosed. Many insubstantial modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the disclosure. The scope of the claims is intended to broadly cover the disclosed embodiments and any such modification. Further, the following clauses represent additional embodiments of the disclosure and should be considered within the scope of the disclosure:

[0024] Clause 1, a metal patch for patching a downhole well casing, the metal patch comprising: a metal sealant having a shape congruent with a section of the downhole well casing and transition-able from a first state to a second state in response to a chemical reaction with water; wherein the metal sealant in response to the chemical reaction with water expands;

[0025] Clause 2, the metal patch of clause 1 wherein the metal sealant is one of an alkaline earth metal and a transition metal;

[0026] Clause 3, the metal patch of clause 1 wherein the metal sealant is a compound of magnesium or aluminum and at least one alloying element, wherein the at least one alloying element is selected from a group consisting of Al, Zn, Mn, Zr, Y, Nd, Gd, Ag, Ca, Sn, and RE;

[0027] Clause 4, the metal patch of clause 3 wherein the metal sealant is alloyed with a dopant that promotes corrosion;

[0028] Clause 5, the metal patch of clause 3 wherein the at least one alloying element is an element that inhibits passivation;

[0029] Clause 6, the metal patch of clause 1 wherein the first state is one of: $\text{Mg} + 2\text{H}_2\text{O}$; $\text{Al} + 3\text{H}_2\text{O}$; and $\text{Ca} + \text{H}_2\text{O}$;

[0030] Clause 7, the metal patch of clause 1 wherein the second state contains a solid that consists of one of: $\text{Mg}(\text{OH})_2$; $\text{Al}(\text{OH})_3$; and $\text{Ca}(\text{OH})_2$;

[0031] Clause 8, a method of using a metal patch for patching a well casing downhole in a wellbore environment, the method comprising: assembling a metal sealant with a base, wherein the metal sealant and the base have a diameter smaller than the diameter of a section of the well casing; coupling the assembled metal sealant and base to the well casing using a downhole running tool and expandable device; and wherein the metal sealant is transition-able from a first state to a second state in response to chemical reaction with a water-based fluid; wherein the metal sealant in response to chemical reaction with water expands and hardens;

[0032] Clause 9, the method of clause 8 wherein the metal sealant is one of an alkaline earth metal, a transition metal, and a metal oxide;

[0033] Clause 10, the method of clause 8 wherein the metal sealant is a compound of magnesium and at least one alloy, wherein the at least one alloy is selected from a group consisting of Al, Zn, Mn, Zr, Y, Nd, Gd, Ag, Ca, Sn, and RE;

[0034] Clause 11, the method of clause 10 wherein the at least one alloy is alloyed with a dopant that promotes corrosion;

[0035] Clause 12, the method of clause 10 wherein the at least one alloy is alloyed with a dopant that inhibits passivation;

[0036] Clause 13, The method of clause 9 wherein the first state is one of: $\text{Mg} + 2\text{H}_2\text{O}$; $\text{Al} + 3\text{H}_2\text{O}$; and $\text{Ca} + \text{H}_2\text{O}$ and wherein the second state is one of: $\text{Mg}(\text{OH})_2 + \text{H}_2$; $\text{Al}(\text{OH})_3 + 3/2 \text{H}_2$; and $\text{Ca}(\text{OH})_2$;

[0037] Clause 14, a system for patching a downhole well casing, the system comprising: a base having a shape congruent with a section of the well casing; a metal sealant couple-able with the base and having a shape congruent with a section of the downhole well casing and transition-able from a first state to a second state in response to hydrolysis; and wherein the metal sealant in response to hydrolysis expands and hardens;

[0038] Clause 15, the system of clause 14 wherein the metal sealant is one of an alkaline earth metal, a transition metal, and a metal oxide;

[0039] Clause 16, the system of clause 14 wherein the metal sealant is a compound of magnesium and at least one alloy, wherein the at least one alloy is selected from a group consisting of Al, Zn, Mn, Zr, Y, Nd, Gd, Ag, Ca, Sn, and RE;

[0040] Clause 17, the system of clause 16 wherein the at least one alloy is alloyed with a dopant that promotes corrosion;

[0041] Clause 18, the system of clause 16 wherein the at least one alloy is alloyed with a dopant that inhibits passivation;

[0042] Clause 19, the system of clause 14 wherein the first state is one of: $\text{Mg} + 2\text{H}_2\text{O}$; $\text{Al} + 3\text{H}_2\text{O}$; and $\text{Ca} + \text{H}_2\text{O}$; and

[0043] Clause 20, the system of clause 14 wherein the second state is one of: $\text{Mg}(\text{OH})_2 + \text{H}_2$; $\text{Al}(\text{OH})_3 + 3/2 \text{H}_2$; and $\text{Ca}(\text{OH})_2$.

What is claimed is:

1. A metal patch for patching a downhole well casing, the metal patch comprising:
 - a base having a tubular shape; and
 - a metal sealant having a tubular shape;
 - wherein the metal sealant and the base have a diameter smaller than a diameter of a section of the well casing;
 - wherein the diameter of the metal sealant is larger than the diameter of the base;
 - wherein the metal sealant is disposed adjacent to the base;
 - wherein the metal sealant transitions from a first state to a second state in response to a hydration reaction with a water-based fluid; wherein the first state consists of a metal or metal alloy;
 - wherein the second state is a hydroxide reaction product of the hydration reaction; wherein the second state comprises a larger volume than the first state; and
 - wherein the hydroxide reaction product patches the well casing by forming a seal against the well casing.
2. The metal patch of claim 1 wherein the metal or metal alloy of the first state of the metal sealant consists of an alkaline earth metal, a transition metal, a metal oxide, or a combination thereof.
3. The metal patch of claim 2 wherein the metal or metal alloy of first state of the metal sealant consists of at least one element, wherein the at least one element is selected from a group consisting of Al, Zn, Mn, Zr, Y, Nd, Gd, Ag, Ca, Sn, Mg, Ga, and RE.
4. The metal patch of claim 2 wherein the first state of the metal sealant further comprises a dopant that accelerates the hydration reaction.
5. The metal patch of claim 3 wherein the first state of the metal sealant comprises magnesium.
6. The metal patch of claim 1 wherein the first state is one of: $\text{Mg} + 2\text{H}_2\text{O}$; $\text{Al} + 3\text{H}_2\text{O}$;

and $\text{Ca} + \text{H}_2\text{O}$.

7. The metal patch of claim 1 wherein the formed hydroxide reaction product is selected from the group consisting of magnesium hydroxide, aluminum hydroxide, calcium hydroxide, and any combination thereof.

8. A method for patching a well casing downhole in a wellbore environment, the method comprising:

assembling a metal sealant with a base, wherein the base has a tubular shape; wherein the metal sealant and the base have a diameter smaller than a diameter of a section of the well casing; wherein the metal sealant has a tubular shape and; wherein the diameter of the metal sealant is larger than the diameter of the base; and wherein the metal sealant is disposed adjacent to the base;

coupling the assembled metal sealant and base to the well casing using a downhole running tool and expandable device;

wherein the metal sealant transitions from a first state to a second state in response to a hydration reaction with a water-based fluid;

wherein the first state consists of a metal or metal alloy; wherein the second state is a hydroxide reaction product of the hydration reaction;

wherein the second state comprises a larger volume than the first state; and

wherein the hydroxide reaction product patches the well casing by forming a seal against the well casing.

9. The method of claim 8 wherein the metal or metal alloy of the first state of the metal sealant consists of an alkaline earth metal, a transition metal, a metal oxide, or a combination thereof.

10. The method of claim 8 wherein the metal or metal alloy of first state of the metal sealant consists of at least one element selected from the group consisting of Mg, Al, Zn, Mn, Zr, Y, Nd, Gd, Ag, Ca, Sn, and RE.

11. The method of claim 10 wherein the first state of the metal sealant further

comprises a dopant that accelerates the hydration reaction.

12. The method of claim 10 wherein the first state of the metal sealant comprises magnesium.

13. The method of claim 8 wherein the formed hydroxide reaction product is selected from the group consisting of magnesium hydroxide, aluminum hydroxide, calcium hydroxide, and any combination thereof.

14. A system for patching a downhole well casing, the system comprising:
a base having a tubular shape congruent with a section of the well casing;
a metal sealant couple-able with the base and having a tubular shape congruent with a section of the downhole well casing;

wherein the metal sealant and the base have a diameter smaller than a diameter of a section of the well casing;

wherein the diameter of the metal sealant is larger than the diameter of the base;

wherein the metal sealant is disposed adjacent to the base;

wherein the metal sealant transitions from a first state to a second state in response to a hydration reaction with a water-based fluid; wherein the first state consists of a metal or metal alloy;

wherein the second state is a hydroxide reaction product of the hydration reaction;

wherein the second state comprises a larger volume than the first state; and

and

wherein the hydroxide reaction product patches the well casing by forming a seal against the well casing.

15. The system of claim 14 wherein the metal or metal alloy of the first state of the metal sealant consists of an alkaline earth metal, a transition metal, and a metal oxide.

16. The system of claim 14 wherein the metal or metal alloy of first state of the metal sealant consists of at least one element, wherein the at least one element is selected from a group consisting of Al, Zn, Mn, Zr, Y, Nd, Gd, Ag, Ca, Sn, and RE.
17. The system of claim 16 wherein the first state of the metal sealant further comprises a dopant that accelerates the hydration reaction.
18. The system of claim 16 wherein the first state of the metal sealant comprises magnesium.
19. The system of claim 14 wherein the first state is one of: $\text{Mg} + 2\text{H}_2\text{O}$; $\text{Al} + 3\text{H}_2\text{O}$; and $\text{Ca} + \text{H}_2\text{O}$.
20. The system of claim 14 wherein the formed hydroxide reaction product is selected from the group consisting of magnesium hydroxide, aluminum hydroxide, calcium hydroxide, and any combination thereof.