

EXPANDABLE METAL GAS LIFT MANDREL PLUG

BACKGROUND

[0001] To obtain hydrocarbon fluids from a formation within the earth, a wellbore is drilled into the earth to intersect an area of interest within the formation. The wellbore may then be “completed” by inserting casing within the wellbore and setting the casing therein using cement. In the alternative, the wellbore may remain uncased (an “open hole wellbore”), or may become only partially cased. Regardless of the form of the wellbore, production tubing is typically run into the wellbore primarily to convey production fluid (e.g., hydrocarbon fluid, which may also include water) from the area of interest within the wellbore to the surface of the wellbore.

[0002] Often, pressure within the wellbore is insufficient to cause the production fluid to naturally rise through the production tubing to the surface of the wellbore. Thus, to carry the production fluid from the area of interest within the wellbore to the surface of the wellbore, artificial lift means are sometimes necessary.

[0003] One artificial lift means is a gas lift system. Gas lift systems typically include several gas lift valves, which are often internal one-way valves spaced in a gas lift mandrel located in the inner diameter of the production tubing. The gas lift valves allow fluid flow from an annulus between the casing and the production tubing to lift production fluid flowing through the production tubing, yet the gas lift valves prevent fluid flow from the longitudinal bore running through the production tubing into the annulus.

[0004] During the course of a gas lift operation, access to the gas lift valves by the operator is often necessary for several reasons. First, the gas lift valves often require maintenance, repair, or replacement, for example if the valve is leaking fluid flow into the annulus from the production tubing. Second, it is often necessary to remove the gas lift valves, and insert a gas lift mandrel

plug in their place. Unfortunately, existing gas lift mandrel plugs experience certain drawbacks, particularly with efficiently plugging eroded gas lift mandrels. Accordingly, what is needed in the art is an improved gas lift mandrel plug that does not experience the drawbacks of those that currently exist.

BRIEF DESCRIPTION

[0005] Reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0006] FIG. 1 is a perspective view of a well system employing a gas lift mandrel plug according to the disclosure;

[0007] FIG. 2 is a section view of one embodiment of a gas lift mandrel plug according to the disclosure;

[0008] FIG. 3 is a section view of another embodiment of a gas lift mandrel plug according to the disclosure;

[0009] FIG. 4 is a section view of yet another embodiment of a gas lift mandrel plug according to the disclosure; and

[0010] FIG. 5 is a section view of another embodiment of a gas lift mandrel plug according to the disclosure.

DETAILED DESCRIPTION

[0011] In the drawings and descriptions that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals, respectively. The drawn figures are not necessarily, but may be, to scale. Certain features of the disclosure may be shown exaggerated in scale or in somewhat schematic form and some details of certain elements may

not be shown in the interest of clarity and conciseness. The present disclosure may be implemented in embodiments of different forms. Specific embodiments are described in detail and are shown in the drawings, with the understanding that the present disclosure is to be considered an exemplification of the principles of the disclosure, and is not intended to limit the disclosure to that illustrated and described herein. It is to be fully recognized that the different teachings of the embodiments discussed herein may be employed separately or in any suitable combination to produce desired results. Moreover, all statements herein reciting principles and aspects of the disclosure, as well as specific examples thereof, are intended to encompass equivalents thereof. Additionally, the term, "or," as used herein, refers to a non-exclusive or, unless otherwise indicated.

[0012] Unless otherwise specified, use of the terms "connect," "engage," "couple," "attach," or any other like term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described.

[0013] Unless otherwise specified, use of the terms "up," "upper," "upward," "uphole," "upstream," or other like terms shall be construed as generally toward the surface of the well; likewise, use of the terms "down," "lower," "downward," "downhole," or other like terms shall be construed as generally toward the bottom, terminal end of a well, regardless of the wellbore orientation. Use of any one or more of the foregoing terms shall not be construed as denoting positions along a perfectly vertical or horizontal axis. Unless otherwise specified, use of the term "subterranean formation" shall be construed as encompassing both areas below exposed earth and areas below earth covered by water, such as ocean or fresh water.

[0014] Referring to FIG. 1, depicted is a well system 100 including an exemplary operating environment that the apparatuses, systems and methods disclosed herein may be employed. For example, the well system 100 could use a gas lift mandrel plug according to any of the embodiments, aspects, applications, variations, designs, etc. disclosed in the following paragraphs. The well system 100 includes a typical gas lift system 110, as shown in FIG. 1. Generally, compressed gas G is injected into an annulus 115 between an outer diameter of a wellbore tubular (e.g., production tubing string 120) and the inner diameter of casing 125 within the wellbore 130. A valve system 135 supplies injection gas G and allows produced fluid to exit the gas lift system 110.

[0015] Spaced within the production tubing string 120 are gas lift mandrels 140 having gas lift valves 145 within side pockets 190 thereof. In the illustrated embodiment, the side pockets 190 of the gas lift mandrels 140 are offset from the centerline of the production tubing string 120. The gas lift valves 145, in the illustrated embodiment, are one-way valves used to allow gas to flow from the annulus 115 into the production tubing string 120 and to disallow gas to flow from the production tubing string 120 into the annulus 115.

[0016] A production packer 150 located at a lower end of the production tubing string 120 forces the flow of production fluid P from a reservoir or zone of interest in a subterranean formation 155 up through the production tubing string 120 instead of up through the annulus 115. Additionally, the production packer 150 forces the gas flow from the annulus 115 into the production tubing string 120 through the gas lift valves 145, as gas G is not allowed to flow further down into the annulus 115 past the production packer 150.

[0017] In operation, production fluid P flows from the subterranean formation 155 into the wellbore 130 through perforations 160 in the casing 125 and the subterranean formation 155.

The production fluid P flows into the production tubing string 120. When it is desired to lift the production fluid P with gas G, compressed gas G is introduced into the annulus 115. The gas lift valves 145 allow the gas G to flow into the production tubing string 120 while preventing the flow of the production fluid P into the annulus 115 through the gas lift valves 145.

[0018] The well system 100 of FIG. 1 additionally includes a gas lift mandrel plug 170 manufactured and designed according to the disclosure. In certain situations one or more of the gas lift valves 145 need to be removed and/or the need for production gas G is no longer necessary. In such a situation, the one or more of the gas lift valves 145 may be removed from one or more of the side pockets 190, and thereafter the one or more side pockets 190 may be sealed to prevent gas, debris, or contaminants from entering the production tubing 120. In some embodiments, a gas lift mandrel plug 170 according to the disclosure may be inserted into the side pocket 190 to seal the gas lift mandrel 140. In this scenario, the gas lift valve 145 may be removed from the side pocket 190 using one or more different types of intervention tools. The gas lift mandrel plug 170 may then be connected with the intervention tool, or a different intervention tool, and deployed downhole and placed into the side pocket 190.

[0019] The gas lift mandrel plug 170, in accordance with the disclosure, may comprise a metal sealant configured to expand in response to hydrolysis, such that the gas lift mandrel plug 170 seals the side pocket 190 in response to hydrolysis. As the gas lift mandrel plug 170 expands, it may enlarge to fit within the various different surface irregularities (e.g., cracks, crevices, debris, etc.) in the side pocket 190. Additional details of the gas lift mandrel plug 170 are discussed below.

[0020] Turning to FIG. 2, illustrated is a gas lift mandrel plug 200 manufactured and designed in accordance with the disclosure. The gas lift mandrel plug 200 may include an elongate member

210 having a proximal end 215 and a distal end 220. The term elongate member, as used herein, is intended to include members having a length significantly greater than its width and/or diameter, and may include cross-sectional shapes including circles, ovals, polygons, irregular shapes, etc. In the particular embodiment illustrated in FIG. 2, the elongate member 210 has a generally circular cross-section, and thus is a generally cylindrical member. In some embodiments, the distal end 220 may be tapered, and in some embodiments, may include a tapered nose 225 such that the gas lift mandrel plug 200 may more easily enter a side pocket of a wellbore casing, such as side pocket 190. For example, the tapered nose 225 may reduce the surface resistance as the distal end 220 is turned radially outward to initially enter the side pocket and then again to turn vertically downhole as the gas lift mandrel plug 200 is positioned into the side pocket.

[0021] The proximal end 215 may be configured to connect with an intervention tool. In the embodiment of FIG. 2, the proximal end 215 includes an intervention tool connector 230 that forms an integral part of the elongate member 210. The intervention tool connector 230 may comprise any type of connection (e.g., threaded connection, press fit connection, shear pin connection, etc.) consistent with the disclosure. In some embodiments, the same intervention tool may be used to both remove the gas lift valve and then place the gas lift mandrel plug 200. In other embodiments, different intervention tools may be used to remove the gas lift valve and place the gas lift mandrel plug 200.

[0022] The elongate member 210 may have a length (l) and a width (w). In some embodiments, the length (l) may be about 700 mm (e.g., approximately 27.56 in) or less. In another embodiment, the length (l) may be about 610 mm (e.g., approximately 2 ft.) or less, and in yet another embodiment the length (l) may be about 322 mm (e.g., approximately 12.7 in.) or less.

In some embodiments, the elongate member 210 may have a width (w) of about 51 mm (e.g., approximately 2 in.) or less. In another embodiment, the width (w) may be about 26 mm (e.g., approximately 1 in.) or less, and in yet another embodiment may be about 13 mm (e.g., approximately ½ in.) or less. The elongate member 210 may, in one embodiment, have a length (l) to width (w) ratio of greater than about 6.3 to 1. In another embodiment, the elongate member 210 may have a length (l) to width (w) ratio of less than about 48 to 1. In yet another embodiment, the elongate member 210 may have a length (l) to width (w) ratio ranging from about 12 to 1 to about 14 to 1, and in another embodiment the elongate member 210 may have a length (l) to width (w) ratio ranging from about 12.25 to 1 to about 12.5 to 1.

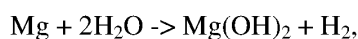
[0023] In some embodiments, all or part of the gas lift mandrel plug 200 may be fabricated using an expanding metal sealant configured to expand in response to hydrolysis. The expanding metal sealant, in some embodiments, may be described as expanding to a cement like material that seals a gas lift valve in a side pocket of a side pocket mandrel, such as, e.g. side pocket mandrel 140 shown in FIG. 1. In other words, the metal goes from metal to micron-scale particles and then these particles lock together to, in essence, seal the gas lift mandrel. The reaction may, in certain embodiments, occur in less than 2 days in a reactive fluid and in downhole temperatures. Nevertheless, the time of reaction may vary depending on the reactive fluid.

[0024] In some embodiment the reactive fluid may be a brine solution such as may be produced during well completion activities, and in other embodiments, the reactive solution may be one of the additional solutions discussed herein. The metal, pre-expansion, is electrically conductive in certain embodiments. The metal may be machined to any specific size/shape, extruded, formed, cast or other conventional ways to get the desired shape of a metal. Metal, pre-expansion, in

certain embodiments has a yield strength greater than about 8,000 psi, e.g., 8,000 psi +/- 50%. The metal, in this embodiment, has a minimum dimension greater than about 1.25 mm (e.g., approximately 0.05 inches).

[0025] The hydrolysis of any metal can create a metal hydroxide. The formative properties of alkaline earth metals (Mg - Magnesium, Ca - Calcium, etc.) and transition metals (Zn - Zinc, Al - Aluminum, etc.) under hydrolysis reactions demonstrate structural characteristics that are favorable for use with the present disclosure. Hydration results in an increase in size from the hydration reaction and results in a metal hydroxide that can precipitate from the fluid.

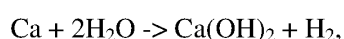
[0026] The hydration reactions for magnesium is:



where $\text{Mg}(\text{OH})_2$ is also known as brucite. Another hydration reaction uses aluminum hydrolysis. The reaction forms a material known as Gibbsite, bayerite, and norstrandite, depending on form. The hydration reaction for aluminum is:



Another hydration reactions uses calcium hydrolysis. The hydration reaction for calcium is:



Where $\text{Ca}(\text{OH})_2$ is known as portlandite and is a common hydrolysis product of Portland cement. Magnesium hydroxide and calcium hydroxide are considered to be relatively insoluble in water. Aluminum hydroxide can be considered an amphoteric hydroxide, which has solubility in strong acids or in strong bases.

[0027] In an embodiment, the metallic material used can be a metal alloy. The metal alloy can be an alloy of the base metal with other elements in order to either adjust the strength of the metal

alloy, to adjust the reaction time of the metal alloy, or to adjust the strength of the resulting metal hydroxide byproduct, among other adjustments. The metal alloy can be alloyed with elements that enhance the strength of the metal such as, but not limited to, Al - Aluminum, Zn - Zinc, Mn - Manganese, Zr - Zirconium, Y - Yttrium, Nd - Neodymium, Gd - Gadolinium, Ag - Silver, Ca - Calcium, Sn - Tin, and Re - Rhenium, Cu - Copper. In some embodiments, the alloy can be alloyed with a dopant that promotes corrosion, such as Ni - Nickel, Fe - Iron, Cu - Copper, Co - Cobalt, Ir - Iridium, Au - Gold, C - Carbon, gallium, indium, mercury, bismuth, tin, and Pd - Palladium. The metal alloy can be constructed in a solid solution process where the elements are combined with molten metal or metal alloy. Alternatively, the metal alloy could be constructed with a powder metallurgy process. The metal can be cast, forged, extruded, or a combination thereof.

[0028] Optionally, non-expanding components may be added to the starting metallic materials. For example, ceramic, elastomer, glass, or non-reacting metal components can be embedded in the expanding metal or coated on the surface of the metal. Alternatively, the starting metal may be the metal oxide. For example, calcium oxide (CaO) with water will produce 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 expanding metal is formed in a serpentine reaction, a hydration and metamorphic reaction. In one variation, the resultant material resembles a mafic material. Additional ions can be added to the reaction, including silicate, sulfate, aluminate, and phosphate. The metal can be alloyed to increase the reactivity or to control the formation of oxides.

[0029] Referring now FIG. 3, there is shown another embodiment of a gas lift mandrel plug 300 according to the disclosure. The gas lift mandrel plug 300 may include an elongate member 210 having a proximal end 215 and a distal end 220. In this embodiment, the proximal end 215 includes an intervention tool connector 330. In the illustrated embodiment of FIG. 3, the intervention tool connector 330 is not integrally manufactured with the elongate member 210, and thus is coupled with the elongate member 210 via threaded connection 340, among other available connections. The intervention tool connector 330, in this embodiment, might comprise a material different from the elongate member 210, and more particularly a material that does not expand as a result of hydrolysis.

[0030] Referring now to FIG. 4, there is shown yet another embodiment of a gas lift mandrel plug 400 according to the disclosure. The gas lift mandrel plug 400 may include an elongate member 210 having a proximal end 215 and a distal end 220. The proximal end 215 includes an intervention tool connector 330, which in this embodiment is coupled with the elongate member 210 via threaded connection 340. One or more swellable members 450 may be coupled radially about the elongate member 210. The swellable members 450 may comprise a swellable rubber that is configured to expand in response to contact with one or more different types of fluids. In one embodiment, the reactive fluid may be a diesel solution or other water-based solutions discussed herein. The elongate member 210 may comprise a metal sealant configured to expand in response to hydrolysis. In some embodiments, the metal sealant may react with a brine solution, or the other solutions discussed above may be used.

[0031] Referring now to FIG. 5, there is shown yet another embodiment of a gas lift mandrel plug 500 according to the disclosure. The gas lift mandrel plug 500 may include an elongate member 210 having a proximal end 215 and a distal end 220. In this embodiment, the proximal

end 215 includes an intervention tool connector 330 which may be coupled with the elongate member 210 via threaded connection 340. The elongate member 210, in this embodiment, may be radially surrounded by a sleeve 560. The sleeve 560 may be employed for one or more different reasons. In one situation, the sleeve 560 is a swellable rubber sleeve configured to expand in response to contact with one or more different types of fluids. In one embodiment, the reactive fluid may be a diesel solution, and the sleeve 560 swells to further seal the gas lift mandrel. In another situation, the sleeve 560 is configured to delay the expansion of the elongate member 210, for example by providing a temporary barrier between the elongate member 210 and the hydrolysis solution.

[0032] Aspects disclosed herein include:

A. A gas lift mandrel plug for use in a wellbore. The gas lift mandrel plug, in one embodiment, includes an elongate member having a proximal end and a distal end; wherein the elongate member comprises a metal sealant configured to expand in response to hydrolysis; and wherein the elongate member is configured to seal a side pocket of a wellbore tubular in response to hydrolysis.

B. A well system. In one embodiment, the well system includes a wellbore tubular; a side pocket located within the wellbore tubular; a gas lift mandrel plug positioned in and sealing the side pocket, the gas lift mandrel plug comprising: an elongate member having a proximal end and a distal end, wherein the proximal end is configured to connect with an intervention tool; and wherein the elongate member comprises a metal sealant configured to expand in response to hydrolysis.

C. A method of using a gas lift mandrel plug in a well system. The method, in one embodiment, includes removing a gas lift valve from a side pocket located within a wellbore tubular; positioning a gas lift mandrel plug into the side pocket, the gas lift mandrel plug comprising an elongate member having a proximal end and a distal end, wherein the proximal end is configured to connect with an intervention tool; wherein the elongate member comprises a metal sealant configured to expand in response to hydrolysis; and wherein the elongate member is configured to seal a side pocket of a downhole casing in response to hydrolysis.

Aspects A, B, and C may have one or more of the following additional elements in combination: Element 1: wherein the distal end is tapered; Element 2: wherein the proximal end includes an intervention tool connector; Element 3: wherein the intervention tool connector is threadedly attached with the elongate member; Element 4: wherein the intervention tool connector forms an integral part of the elongate member; Element 5: wherein the elongate member is a cylindrical member, and further wherein a ratio of a length (l) to width (w) of the cylindrical member ranges from about 12 to 1 to about 14 to 1; Element 6: wherein a length (l) of the elongate member is less than 700 mm; Element 7: wherein the metal sealant is configured to expand in response to one of magnesium hydrolysis, aluminum hydrolysis, calcium hydrolysis, and calcium oxide hydrolysis; Element 8: wherein the metal sealant is a magnesium alloy or a magnesium alloy alloyed with at least one of Al, Zn, Mn, Zr, Y, Nd, Gd, Ag, Ca, Sn, and Re; Element 9: further comprising a swellable rubber element placed radially about the elongate member; Element 10: further including subjecting the gas lift mandrel plug to a hydrolysis fluid, the hydrolysis fluid expanding the elongate member to seal the side pocket; and Element 11: wherein hydrolysis forms a structure comprising one of a Brucite, Gibbsite, bayerite, and norstrandite.

[0033] Those skilled in the art to which this application relates will appreciate that other and further additions, deletions, substitutions and modifications may be made to the described embodiments.

WHAT IS CLAIMED IS:

1. A gas lift mandrel plug for use in a wellbore, comprising:
an elongate member having a proximal end and a distal end;
wherein the elongate member comprises a metal sealant configured to expand in response to hydrolysis; and
wherein the elongate member is configured to seal a side pocket of a wellbore tubular in response to hydrolysis.
2. The gas lift mandrel plug according to Claim 1, wherein the distal end is tapered.
3. The gas lift mandrel plug according to Claim 1, wherein the proximal end includes an intervention tool connector.
4. The gas lift mandrel plug according to Claim 3, wherein the intervention tool connector is threadedly attached with the elongate member.
5. The gas lift mandrel plug according to Claim 1, wherein the intervention tool connector forms an integral part of the elongate member.
6. The gas lift mandrel plug according to Claim 1, wherein the elongate member is a cylindrical member, and further wherein a ratio of a length (l) to width (w) of the cylindrical member ranges from about 12 to 1 to about 14 to 1.

7. The gas lift mandrel plug according to Claim 1, wherein a length (l) of the elongate member is less than 700 mm.

8. The gas lift mandrel plug according to Claim 1, wherein the metal sealant is configured to expand in response to one of magnesium hydrolysis, aluminum hydrolysis, calcium hydrolysis, and calcium oxide hydrolysis.

9. The gas lift mandrel plug according to Claim 1, wherein the metal sealant is a magnesium alloy or a magnesium alloy alloyed with at least one of Al, Zn, Mn, Zr, Y, Nd, Gd, Ag, Ca, Sn, and Re.

10. The gas lift mandrel plug according to Claim 1, further comprising a swellable rubber element placed radially about the elongate member.

11. A well system, comprising:
a wellbore tubular;
a side pocket located within the wellbore tubular;
a gas lift mandrel plug positioned in and sealing the side pocket, the gas lift mandrel plug comprising:
an elongate member having a proximal end and a distal end, wherein the proximal end is configured to connect with an intervention tool; and
wherein the elongate member comprises a metal sealant configured to expand in response to hydrolysis.

12. The well system according to Claim 11, wherein the distal end of the elongate member is tapered.

13. The well system according to Claim 11, wherein the proximal end includes an intervention tool connector.

14. The well system according to Claim 11, further comprising a swellable rubber element placed radially about the elongate member.

15. A method of using a gas lift mandrel plug in a well system, the method comprising:

removing a gas lift valve from a side pocket located within a wellbore tubular;

positioning a gas lift mandrel plug into the side pocket, the gas lift mandrel plug comprising an elongate member having a proximal end and a distal end, wherein the proximal end is configured to connect with an intervention tool;

wherein the elongate member comprises a metal sealant configured to expand in response to hydrolysis; and

wherein the elongate member is configured to seal a side pocket of a downhole casing in response to hydrolysis.

16. The method as recited in Claim 15, further including subjecting the gas lift mandrel plug to a hydrolysis fluid, the hydrolysis fluid expanding the elongate member to seal the side pocket.

17. The method as recited in Claim 15, wherein the metal sealant is configured to expand in response to one of magnesium hydrolysis, aluminum hydrolysis, calcium hydrolysis, and calcium oxide hydrolysis.

18. The method of claim 15 wherein hydrolysis forms a structure comprising one of a Brucite, Gibbsite, bayerite, and norstrandite.

19. The method as recited in Claim 15, wherein the metal sealant is a magnesium alloy or a magnesium alloy alloyed with at least one of Al, Zn, Mn, Zr, Y, Nd, Gd, Ag, Ca, Sn, and Re.