

DOWNHOLE FRACTURING TOOL ASSEMBLY

BACKGROUND

[0001] The process of induced hydraulic fracturing involves injecting a fracturing fluid at a high pressure into a fracturing zone of interest. Small fractures are formed, allowing fluids, such as gas and petroleum to migrate into the wellbore for producing to the surface. Often the fracturing fluid is mixed with proppants (e.g., sand) and chemicals in water so that once the pressure is removed, the sand or other particles hold the fractures open. Other fracturing fluids use concentrated acid to dissolve parts of the formation so that once the pressure is removed, dissolved tunnels are formed in the formation. Hydraulic fracturing is a type of well stimulation, whereby the fluid removal is enhanced, and well productivity is increased.

[0002] Multi-stage hydraulic fracturing is an advancement to produce fluids along a single wellbore or fracturing string. Multiple stages allow the fracturing fluid to be targeted at individual zones. Zones are typically fractured in a sequence. Previously fractured zones are isolated from the next zones to be fracture.

[0003] In a multi-stage fracturing process, previously fractured zones must be isolated from the zones that are going to be stimulated. Traditionally, isolation is performed with a ball that lands either on a ball seat or on a fracturing plug. The ball seats or fracturing plugs are positioned within zones of interest in the wellbore. Hydraulic fracturing can be performed in stages by selectively activating sleeves by the ball landing on a ball seat which also isolates the particular zones of interest from the previously fractured zones. Each target zone can be hydraulically fractured, stage by stage (e.g., toe to heel).

[0004] What are needed in the art are improved apparatus, systems, and methods for fracturing multi-stage zones.

BRIEF DESCRIPTION

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

[0006] FIG. 1 schematically illustrates a well system, including a downhole fracturing tool assembly, and a downhole zonal isolation assembly, each of which are designed, manufactured and operated according to the present disclosure;

[0007] FIG. 2A schematically illustrates an alternative well system designed, manufactured, and operated according to one embodiment of the disclosure;

[0008] FIG. 2B schematically illustrates an alternative well system designed, manufactured, and operated according to one embodiment of the disclosure;

[0009] FIGs. 3A-3D illustrate detailed views of a first sliding sleeve, a second sliding sleeve, a rotating sleeve, and a rotating ball valve, each of which are designed, manufactured and operated according to the disclosure;

[0010] FIGs. 4A-4G illustrate schematic views of one embodiment of a method for fracturing a well system; and

[0011] FIGs. 5A-5G illustrate schematic views of another embodiment of a method for fracturing a well system.

DETAILED DESCRIPTION

[0012] 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 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.

[0013] 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.

[0014] 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. 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 ground; 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 axis. In some instances, a part near the end of the well can be horizontal or even slightly directed upwards. In such instances, the terms “up,” “upper,” “upward,” “uphole,” “upstream,” or other like terms shall be used to represent the toward the surface end of a well. 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.

[0015] The term “proximate,” as used herein with regard to the placement of two features relative to one another, means that the two features are located within about 150 meters (e.g., about 500 feet) of one another. The term “substantially proximate,” as used herein with regard to the placement of two features relative to one another, means that the two features are located within about 30 meters (e.g., about 100 feet) of one another. The term “ideally proximate,” as used herein with regard to the placement of two features relative to one another, means that the two features are located within about 10 meters (e.g., about 30 feet) of one another.

[0016] Referring initially to FIG. 1, schematically illustrated is a well system 100, including a downhole fracturing tool assembly 190, and a downhole zonal isolation assembly 195, each of which are designed, manufactured and operated according to the present disclosure, and positioned at a desired location in a subterranean formation 110. The well system 100 of FIG. 1, without limitation, includes a semi-submersible platform 115 having a deck 120 positioned over the submerged oil and gas formation 110, which in this embodiment is located below sea floor 125. The platform 115, in the illustrated embodiment, may include a hoisting apparatus/derrick 130 for raising and lowering work string, as well as a fracturing pump 135 for conducting a fracturing process of the subterranean formation 110 according to the disclosure. The well system 100 illustrated in FIG. 1 additionally includes a control system 140 located on the deck 120. The control system 140, in one embodiment, may be used to control the fracturing pump 135, as well as may be communicatively, e.g., electrically, electromagnetically or fluidly, coupled to the downhole fracturing tool assembly 190 and/or downhole zonal isolation assembly 195, among other uses.

[0017] A subsea conduit 145 extends from the platform 115 to a wellhead installation 150, which may include one or more subsea blow-out preventers 155. A wellbore 160 extends through the various earth strata including formation 110. In the embodiment of FIG. 1, wellbore casing 165 is cemented within wellbore 160 by cement 170. In the illustrated embodiment,

wellbore 160 has an initial, generally vertical portion 160a and a lower, generally deviated portion 160b, which is illustrated as being horizontal. It should be noted by those skilled in the art, however, that the downhole fracturing tool assembly 190 and downhole zonal isolation assembly 195 of the present disclosure are equally well-suited for use in other well configurations including, but not limited to, inclined wells, wells with restrictions, non-deviated wells and the like. Moreover, while the wellbore 160 is positioned below the sea floor 125 in the illustrated embodiment of FIG. 1, those skilled in the art understand that the principles of the present disclosure are equally as applicable to other subterranean formations, including those encompassing both areas below exposed earth and areas below earth covered by water such as ocean or fresh water.

[0018] In accordance with one embodiment of the disclosure, the downhole fracturing tool assembly 190 includes a fracturing port cover coupleable to an interior of the wellbore casing 165. The wellbore casing 165, in the example embodiment, would have one or more fracturing ports therein. The downhole fracturing tool assembly 190, in accordance with this embodiment, additionally includes a fracturing port cover actuator coupled to the fracturing port cover, the fracturing port cover actuator operable to move the fracturing port cover between a first position sealing the one or more fracturing ports from an interior of the wellbore casing 165 and a second position exposing the one or more fracturing ports to the interior of the wellbore casing 165. The downhole fracturing tool assembly 190, in accordance with this embodiment, further includes fracturing port cover electronics coupled to the fracturing port cover actuator proximate the fracturing port cover, the fracturing port cover electronics operable (e.g., programmed in one embodiment) to activate the fracturing port cover actuator.

[0019] In accordance with one embodiment of the disclosure, the downhole zonal isolation assembly 195 includes a rotating fracturing valve positionable within the wellbore casing 165 proximate one or more fracturing zones of interest 175a, 175b. The downhole zonal isolation assembly 195, in accordance with this embodiment, additionally includes a rotating fracturing valve actuator coupled to the rotating fracturing valve, and rotating fracturing valve electronics coupled to the rotating fracturing valve actuator, the rotating fracturing valve electronics operable (e.g., programmed in one embodiment) to activate the rotating fracturing valve actuator to move the rotating fracturing valve from a first wellbore casing 165 open position to a second wellbore casing 165 closed position.

[0020] When it is desired to fracture a particular subterranean zone of interest, such as fracturing zones of interest 175a, 175b, the downhole fracturing tool assembly 190 and downhole zonal isolation assembly 195 may be appropriately actuated, for example opening and closing certain ones of the fracturing port covers, as well as opening and closing certain ones of the rotating fracturing valves. Thereafter, pressure within the wellbore 160 may be increased using the fracturing pump 135 and one or more different types of fracturing fluid and/or proppants, thereby forming fractures 180.

[0021] Referring now to FIG. 2A, schematically illustrated is a well system 200a designed, manufactured, and operated according to one embodiment of the disclosure. The well system 200a, in the illustrated embodiment, includes first and second downhole fracturing tool assemblies 210a, 210b, and first and second downhole zonal isolation assemblies 250a, 250b, each of which are designed, manufactured, and operated according to one embodiment of the disclosure. While the well system 200a illustrated in FIG. 2A includes first and second downhole fracturing tool assemblies 210a, 210b, and first and second downhole zonal isolation assemblies 250a, 250b, other embodiments may exist wherein a single downhole fracturing tool assembly and/or single downhole zonal isolation assembly is used, or alternatively wherein three or more downhole fracturing assemblies and/or three or more downhole zonal isolation assemblies are used. It should further be noted that while the downhole fracturing tool assembly and downhole zonal isolation assembly may be used together, as illustrated in FIG. 2A, other embodiments may exist wherein the downhole fracturing tool assembly is used without the downhole zonal isolation assembly, or alternatively the downhole zonal isolation assembly is used without the downhole fracturing tool assembly.

[0022] In the embodiment illustrated in FIG. 2A, the first and second downhole fracturing tool assemblies 210a, 210b, and first and second downhole zonal isolation assemblies 250a, 250b, are positioned within a wellbore casing 270 located in a wellbore 280, all of which are located within a subterranean formation 290. In the illustrated embodiment shown, the first and second downhole fracturing tool assemblies 210a, 210b, and first and second downhole zonal isolation assemblies 250a, 250b are deployed at first and second fracturing zones of interest 295a, 295b (e.g. similar to the fracturing zones of interest 175a, 175b of FIG. 1). For purposes of the present discussion, the first downhole fracturing tool assembly 210a, first zonal isolation assembly 250a, and first fracturing zone of interest 295a are uphole of the second downhole fracturing tool

assembly 210b, second zonal isolation assembly 250a, and second fracturing zone of interest 295a, respectively. Accordingly, the first downhole fracturing tool assembly 210a, first zonal isolation assembly 250a, and first fracturing zone of interest 295a might be in a heel of the wellbore 290, whereas the second downhole fracturing tool assembly 210b, second zonal isolation assembly 250a, and second fracturing zone of interest 295b might be in a toe of the wellbore 290.

[0023] In accordance with one embodiment of the disclosure, the wellbore casing 270, at each of the fracturing zones of interest 295a, 295b, includes one or more fracturing ports 275a, 275b therein. The fracturing ports 275a, 275b, in this embodiment, provide a fluid path through the wellbore casing 270, as might be required to hydraulically fracture each of the fracturing zones of interest 295a, 295b. The number and location of the one or more fracturing ports 275a, 275b may vary greatly, for example based upon the design of the well system 200a.

[0024] In accordance with one embodiment of the disclosure, each of the first and second downhole fracturing tool assemblies 210a, 210b includes a fracturing port cover 215a, 215b coupled to an interior of the wellbore casing 270 proximate the one or more fracturing ports 275a, 275b. In accordance with this embodiment, the fracturing port covers 215a, 215b are operable to move between a first position sealing the one or more fracturing ports 275a, 275b from an interior of the wellbore casing 270 (see, for example fracturing port cover 215a) and a second position exposing the one or more fracturing ports 275a, 275b to the interior of the wellbore casing 270 (see, for example fracturing port cover 215b).

[0025] In accordance with one embodiment, the fracturing port covers 215a, 215b are sleeves lining at least a portion of the interior of the wellbore casing 270. For example, the sleeves may be sliding sleeves operable to linearly slide along a length of the wellbore casing 270, such as shown in FIG. 2A. Alternatively, the sleeves may be rotating sleeves operable to rotate about the interior of the wellbore casing 270. In either of these embodiments, the sleeves may move between the first position and the second position. In accordance with another embodiment, the fracturing port covers 215a, 215b are rotating ball valves movable between the first and second positions.

[0026] Turning briefly to FIGs 3A-3C, illustrated are detailed views of a first sliding sleeve 300, a second sliding sleeve 330, and a rotating sleeve 360, respectively, each of which are designed, manufactured and operated according to the disclosure. With initial reference to FIG. 3A, the

sliding sleeve 300, in the illustrated embodiment, has a fully closed region 310 for sealing the one or more fracturing ports, and a screen region 315 for holding proppant within the formation proximate the one or more fracturing ports. The screen region 315 may be small holes within the sliding sleeve 300, or alternatively slits, a fine mesh screen, a wire wrap, or a collection of granules, as is well known in the art, among other configurations. In the embodiment of FIG. 3A, the sliding sleeve 300 would be in the first position covering the one or more fracturing ports when the fully closed region 310 is positioned over the one or more fracturing ports, would be in the second position exposing the one or more fracturing ports when the sliding sleeve 300 is positioned entirely above or entirely below the one or more fracturing ports, and would be in a third position when the screen region 315 is positioned over the one or more fracturing ports.

[0027] With reference to FIG. 3B, the sliding sleeve 330 additionally includes a fully open region 335, which is in addition to the fully closed region 310 and the screen region 315 illustrated in FIG. 3A. In the embodiment of FIG. 3B, the sliding sleeve 330 would be in the first position covering the one or more fracturing ports when the fully closed region 310 is positioned over the one or more fracturing ports, would be in the second position exposing the one or more fracturing ports when the fully open region 335 is positioned over the one or more fracturing ports, and would be in the third position when the screen region 315 is positioned over the one or more fracturing ports. The sliding sleeve 300 and the sliding sleeve 330 primarily differ from one another in that the sliding sleeve 330 additionally includes the fully open region 335. It should be noted that the position of the fully closed region 310, screen region 315, and fully open region 335 in relation to each other may vary from that illustrated in FIGs. 3A and 3B. For example, the fully closed region 310 might be positioned in the middle between the screen region 315 and the fully open region 335, among other configurations.

[0028] With reference to FIG. 3C, the rotating sleeve 360 includes a fully closed region 370, a screen region 375, and a fully open region 380. In this embodiment, the rotating sleeve 360 would rotate about a central axis thereof, for example to position the different regions of the rotating sleeve 360 relative to the one or more fracturing ports in the wellbore casing. In the embodiment of FIG. 3C, the rotating sleeve 360 would be in the first position covering the one or more fracturing ports when the fully closed region 370 is positioned over the one or more fracturing ports, would be in the second position exposing the one or more fracturing ports when the fully open region 380 is positioned over the one or more fracturing ports, and would be in the

third position when the screen region 375 is positioned over the one or more fracturing ports. Again, the position of the fully closed region 370, screen region 375, and fully open region 380, in relation to each other, may vary from that illustrated in FIG. 3C.

[0029] Turning briefly to FIG. 3D, illustrated is an embodiment of a rotating ball valve 390 that might be used as a fracturing port cover, such as the fracturing port covers 215a, 215b illustrated in FIG. 2A. The rotating ball valve 390, in this embodiment, includes a fully closed region 392 and a fully open region 395. In the embodiment of FIG. 3D, the rotating ball valve 390 would be in the first position covering the one or more fracturing ports when the fully closed region 392 is positioned over the one or more fracturing ports, and would be in the second position exposing the one or more fracturing ports when the fully open region 395 is positioned over the one or more fracturing ports.

[0030] Returning to FIG. 2A, the downhole fracturing tool assemblies 210a, 210b additionally include fracturing port cover actuators 220a, 220b, coupled to the fracturing port covers 210a, 210b, respectively. The fracturing port cover actuators 220a, 220b, in this embodiment, are operable to move the fracturing port covers 210a, 210b, between the first position sealing the one or more fracturing ports 275a, 275b from an interior of the wellbore casing 270 and the second position exposing the one or more fracturing ports 275a, 275b to the interior of the wellbore casing 270. The fracturing port cover actuators 220a, 220b are additionally operable to move the fracturing port covers 210a, 210b to the third position (e.g., screen position discussed above), when necessary.

[0031] The fracturing port cover actuators 220a, 220b may comprise many different designs and remain within the scope of the disclosure. Essentially, any actuator that is capable of moving the fracturing port covers 210a, 210b between the first, second and possibly third positions may be used. In certain embodiments, the fracturing port cover actuators 220a, 220b may be capable of moving the fracturing port covers 210a, 210b back and forth between the first, second and possibly third positions. In one specific embodiment, the fracturing port cover actuators 220a, 220b are electric actuators, such as for example a motor with a ball screw, among others. In another embodiment, the fracturing port cover actuators 220a, 220b are hydraulic or pneumatic actuators, and in yet another embodiment the fracturing port cover actuators 220a, 220b are chemical reaction actuators (e.g., gas generator). In yet another embodiment, an electronic rupture disc and an atmospheric chamber could be used as the fracturing port cover actuators

220a, 220b. Again, while only a few example embodiments of fracturing port cover actuators 220a, 220b have been given, those skilled in the art understand that many other fracturing port cover actuators 220a, 220b are within the scope of the disclosure. The downhole fracturing tool assemblies 210a, 210b illustrated in FIG. 2A additionally include fracturing port cover electronics 225a, 225b coupled to the fracturing port cover actuators 220a, 220b proximate the fracturing port covers 210a, 210b.

[0032] In the embodiment of FIG. 2A, the fracturing port cover electronics 225a, 225b are operable (e.g., programmed in one embodiment) to activate the fracturing port cover actuators 220a, 220b, for example to move the fracturing port covers 210a, 210b between the first, second and possibly third positions. The fracturing port cover electronics 225a, 225b may be programmed to activate the fracturing port cover actuators 220a, 220b based upon variety of different criteria. In one embodiment, the fracturing port cover electronics 225a, 225b are programmed to activate the fracturing port cover actuators 220a, 220b based upon changes in time. In another embodiment, the fracturing port cover electronics 225a, 225b are programmed to activate the fracturing port cover actuators 220a, 220b based upon changes in temperature (e.g., as the temperatures rise and fall as the well system undergoes different fracturing processes), or based upon changes in pressure (e.g., as the pressures rise and fall as the well system undergoes different fracturing processes), or even based upon changes in flow (e.g., as the flow of the fluid increases and decreases as the well system undergoes different fracturing processes).

[0033] In yet another embodiment, the fracturing port cover electronics 225a, 225b may be programmed to activate the fracturing port cover actuators 220a, 220b based upon receiving a signal. For example, the fracturing port cover electronics 225a, 225b may be programmed to activate the fracturing port cover actuators 220a, 220b based upon receiving a signal encoded on the wellbore casing 270 or within fluid within the wellbore casing 270. In yet another embodiment, the fracturing port cover electronics 225a, 225b are programmed to activate the fracturing port cover actuators 220a, 220b based upon receiving a signal from a drop ball or drop plug traversing down the wellbore casing 270. In yet other embodiments, combinations of the above may be used. While a handful of different embodiments have been given regarding the fracturing port cover electronics 225a, 225b, and specifically what they activate the fracturing port cover actuators 220a, 220b based upon, unless otherwise required the present disclosure

should not be limited to such. The downhole fracturing tool assemblies 210a, 210b illustrated in FIG. 2A additionally include power sources 230a, 230b coupled to the fracturing port cover electronics 225a, 225b proximate the fracturing port cover 210a, 210b.

[0034] In accordance with the disclosure, the power sources 230a, 230b are operable to power the fracturing port cover electronics 225a, 225b. In accordance with one embodiment, the power sources 230a, 230b are downhole battery sources. In one embodiment, the downhole battery source is a primary battery. In a second embodiment, the downhole battery is a secondary battery. In a third embodiment, the downhole battery is a combination of primary and secondary batteries. In this embodiment, the downhole battery sources would have enough power to move the fracturing port covers 210a, 210b between the first, second and optionally third positions at least one time, if not a handful of times or longer. In other embodiments, the downhole battery sources are a first power source, and the downhole fracturing tool assemblies 210a, 210b each include a second power source 235a, 235b. In accordance with this example, the second power sources 235a, 235b could be fluid flow power sources, such as a turbine generator. The second power sources 235a, 235b have the added benefit that they can continue to power the fracturing port cover electronics 225a, 225b, even after the downhole battery sources have been depleted.

[0035] In those embodiments wherein the second power sources 235a, 235b are fluid flow power sources, one or more fluid ports 240a, 240b may couple a throat of the fracture proximate the one or more fracturing ports 275a, 275b and the fluid flow power sources. Accordingly, fluid from the fracture may be used to generate power for the fracturing port cover electronics 225a, 225b, among other powered devices. Furthermore, the fracturing port covers 215a, 215b may be operable to redirect fluid to the fluid flow power source via the fluid port 240a, 240b, and thus determine when and how much energy is generated by the second power sources 235a, 235b.

[0036] In accordance with one embodiment of the disclosure, the first and second downhole zonal isolation assemblies 250a, 250b include rotating fracturing valves 255a, 255b positionable within the wellbore casing 270 proximate the fracturing zones of interest 295a, 295b. The rotating fracturing valves 255a, 255b, in contrast to many downhole valves that may exist today, are operable to isolate fluid from travelling downhole, as opposed to seal fluid from travelling uphole. Moreover, the rotating fracturing valves 255a, 255b are located proximate a fracturing zone of interest, as opposed to proximate an uppermost portion of the wellbore 280.

[0037] The rotating fracturing valves 255a, 255b, in accordance with the disclosure, are operable to move from a first wellbore casing 270 open position (e.g., as shown with the rotating fracturing valve 255a) to a second wellbore casing 270 closed position (e.g., as shown with the rotating fracturing valve 255b). The rotating fracturing valves 255a, 255b may embody many different designs and remain within the scope of the disclosure. In the embodiment illustrated in FIG. 2A, the rotating fracturing valves 255a, 255b are rotating flapper valves that move between the wellbore casing 270 open position and the wellbore casing 270 closed position. In another embodiment, not shown, the rotating fracturing valves 255a, 255b are rotating ball valves. The rotating ball valves would be similar in many, but not all, respects to the rotating ball valve 390 illustrated in FIG. 3D above.

[0038] In certain embodiments, the rotating fracturing valves 255a, 255b, are operable to move back and forth between the wellbore casing 270 open position and the wellbore casing 270 closed position, for example using a spring or another power source. In other embodiments, the rotating fracturing valves 255a, 255b may only move between the wellbore casing 270 open position and the wellbore casing 270 closed position a single time, or vice versa. In those embodiments wherein the rotating fracturing valves 255a, 255b may not return to the wellbore casing 270 open position, they may comprise a dissolvable material. Alternatively, the rotating fracturing valves 255a, 255b may be physically removed, for example by being drilled out, in those embodiments wherein the rotating fracturing valves 255a, 255b may not return to the wellbore casing 270 open position.

[0039] In accordance with one embodiment of the disclosure, the first and second downhole zonal isolation assemblies 250a, 250b include rotating fracturing valve actuators 260a, 260b coupled to the rotating fracturing valves 255a, 255b, respectively. The rotating fracturing valve actuators 260a, 260b may comprise many different designs and remain within the scope of the disclosure. In one embodiment, the rotating fracturing valve actuators 260a, 260b are release mechanisms, that when released allow fluid within the wellbore casing 270 to move the rotating fracturing valves 255a, 255b from the first wellbore casing 270 open position to the second wellbore casing 270 closed position. In another embodiment, a combination of the release mechanism and a spring moves the rotating fracturing valves 255a, 255b from the first wellbore casing 270 open position to the second wellbore casing 270 closed position. In other embodiments, the rotating fracturing valve actuators 260a, 260b are electric actuators, such as for

example a motor with a ball screw among others. In another embodiment, the rotating fracturing valve actuators 260a, 260b are hydraulic or pneumatic actuators, and in yet another embodiment the rotating fracturing valve actuators 260a, 260b are chemical reaction actuators (e.g., gas generators), among others.

[0040] In the embodiment of FIG. 2A, rotating fracturing valve electronics 262a, 262b are operable (e.g., programmed in certain embodiments) to activate the rotating fracturing valve actuators 260a, 260b, for example to move the rotating fracturing valves 255a, 255b from the first wellbore casing 270 open position to the second wellbore casing 270 closed position. The rotating fracturing valve electronics 262a, 262b may be programmed to activate the rotating fracturing valve actuators 260a, 260b based upon variety of different criteria. In one embodiment, the rotating fracturing valve electronics 262a, 262b are programmed to activate the rotating fracturing valve actuators 260a, 260b based upon changes in time. In another embodiment, the rotating fracturing valve electronics 262a, 262b are programmed to activate the rotating fracturing valve actuators 260a, 260b based upon changes in temperature (e.g., as the temperatures rise and fall as the well system undergoes different fracturing processes), or based upon changes in pressure (e.g., as the pressures rise and fall as the well system undergoes different fracturing processes), or even based upon changes in flow (e.g., as the flow of the fluid increases and decreases as the well system undergoes different fracturing processes). In yet another embodiment, the rotating fracturing valve electronics 262a, 262b are programmed to activate the rotating fracturing valve actuators 260a, 260b based upon receiving a signal. For example, the rotating fracturing valve electronics 262a, 262b are programmed to activate the rotating fracturing valve actuators 260a, 260b based upon receiving a signal encoded on the wellbore casing 270 or within fluid within the wellbore casing 270. In yet another embodiment, the rotating fracturing valve electronics 262a, 262b are programmed to activate the rotating fracturing valve actuators 260a, 260b based upon receiving a signal from a drop ball or drop plug traversing down the wellbore casing 270. In yet other embodiments, combinations of the above may be used. While a handful of different embodiments have been given regarding the rotating fracturing valve electronics 262a, 262b, and specifically what they activate the rotating fracturing valve actuators 260a, 260b based upon, unless otherwise required the present disclosure should not be limited to such. The first and second downhole zonal isolation assemblies 250a, 250b

illustrated in FIG. 2A additionally include power sources 264a, 264b coupled to the rotating fracturing valve electronics 262a, 262b proximate the rotating fracturing valves 255a, 255b.

[0041] In accordance with the disclosure, the power sources 264a, 264b are operable to power the rotating fracturing valve electronics 262a, 262b. In accordance with one embodiment, the power sources 264a, 264b are downhole battery sources. In this embodiment, the downhole battery sources would have enough power to move the rotating fracturing valves 255a, 255b from the first wellbore casing 270 open position to the second wellbore casing 270 closed position at least a single time. In another embodiment, the rotating fracturing valve electronics 262a, 262b are powered by the second power sources 235a, 235b.

[0042] Turning now to FIG. 2B, schematically illustrated is an alternative well system 200b designed, manufactured, and operated according to one embodiment of the disclosure. The well system 200b is similar in many respects to the well system 200a illustrated and described with respect to FIG. 2A. Accordingly, like reference number have been used to reference similar, if not identical, features. The well system 200b differs, for the most part, from the well system 200a, in that the rotating fracturing valves 250c, 250d are mechanically coupled to their associated fracturing port covers 210c, 210d. Accordingly, the fracturing port cover 210c moves with the rotating fracturing valve 250c, and the fracturing port cover 210d moves with the rotating fracturing valve 250c. For example, the rotating fracturing valves 250c, 250d could hinge from their associated fracturing port covers 210c, 210d. Given this configuration, an activation (e.g., closing) of the rotating fracturing valve 250c will slide the fracturing port cover 210c down, and thus close the fracturing ports 275a. Similarly, an activation (e.g., closing) of the rotating fracturing valve 250d will slide the fracturing port cover 210d down, and thus close the fracturing ports 275b.

[0043] In the illustrated embodiment shown in FIG. 2B, the rotating fracturing valve 250d has been moved from the first wellbore casing open position to the second wellbore casing closed position. With the rotating fracturing valve 250d in the closed position, fluid pressure on the flapper of the rotating fracturing valve 250d causes the fracturing port cover 210d to move from a position exposing the one or more fracturing ports 275b to the interior of the wellbore casing to a position sealing the one or more fracturing ports 275b from an interior of the wellbore casing. Such activation will often be conducted in a toe to heel configuration.

[0044] Turning to FIGs. 4A-4G, illustrated are schematic views of one embodiment for fracturing a well system 400, the well system 400 is similar in many respects to the well system 200a discussed above with regard to FIG. 2A. Accordingly, like reference numbers have been used to indicate similar, if not identical, features. In the method discussed with regard to FIGs. 4A-4G, the well system 400 will be fractured in a toe to heel order. Notwithstanding, other embodiments exist wherein the well system 400 is fractured in a heel to toe order. Such a heel to toe fracturing process would likely not use the zonal isolation assemblies, but would in turn use multiple downhole fracturing tool assemblies to provide the zonal isolation, such as described below with respect to FIGs. 5A-5G.

[0045] With initial reference to FIG. 4A, the method begins with the first and second fracturing port covers 215a, 215b in the first position sealing the one or more fracturing ports 275a, 275b. Additionally, the first and second rotating fracturing valves 255a, 255b, are in the first wellbore 270 casing open position. This position of the first and second fracturing port covers 215a, 215b and first and second rotating fracturing valves 255a, 255b may be similar to the run-in-hole position for the downhole fracturing tool assemblies 210a, 210b and downhole zonal isolation assemblies 250a, 250b.

[0046] Turning to FIG. 4B, illustrated is the well system 400 of FIG. 4A after beginning the fracturing process of the second fracturing zone of interest 295b. As shown, the second fracturing port cover 215b has been moved to the second position exposing the one or more fracturing ports 275b, while the first fracturing port cover 215a remains in the first position sealing the one or more fracturing ports 275a. Similarly, the second rotating fracturing valve 255b has been moved to the second wellbore casing 270 closed position, while the first rotating fracturing valve 255a remains in the first wellbore casing 270 open position. Accordingly, the second fracturing zone of interest 295b is isolated from any zones there below using the second rotating fracturing valve 255b, and isolated from the first fracturing zone of interest using the first fracturing port cover 215a.

[0047] The second fracturing port cover 215b and second rotating fracturing valve 255b may be moved from their respective first positions to their respective second positions using the second fracturing port actuator 220b and second rotating fracturing valve actuator 260b, respectively. Moreover, the second fracturing port actuator 220b and second rotating fracturing valve actuator 260b may be activated by the fracturing port cover electronics 225b and rotating

fracturing valve electronics 262b, respectively, based upon any of the criteria discussed above, among other criteria.

[0048] It should be apparent that the second rotating fracturing valve 255b is optional. The well system of FIG. 4B has a flow path from the interior of the tubing to the formation through open fracturing ports 275b and now flow path through obscured fracturing ports 275a. Thus, all of the fluid will exit through fracturing ports 275b. The rotating fracturing valve 255b and 255a are optional in order to help direct the flow towards the open fracturing ports.

[0049] Turning to FIG. 4C, illustrated is the well system 400 of FIG. 4B after fracturing the second zone of interest 295b. Ultimately, the fracturing of the second zone of interest 295b introduces fractures 410 within the subterranean formation 290 proximate the fracturing ports 275b. Those skilled in the art understand the process of fracturing the second zone of interest 295b, including subjecting the exposed second zone of interest 295b to high pressure fluid, which may or may not contain proppant therein.

[0050] Turning to FIG. 4D, illustrated is the well system 400 of FIG. 4C after the optional step of moving the second fracturing port cover 215b back to the first position sealing the one or more fracturing ports 275b. If the second fracturing port cover 215b seals fracturing ports 275b, then rotating fracturing valve 255a might be optional. In another embodiment, the second fracturing port cover 215b could be moved to the third position, such that the screen region is over the one or more fracturing ports 275, thereby holding proppant within the formation 290. In yet another embodiment, the second fracturing port cover 215b could remain in the second position exposing the one or more fracturing ports 275b.

[0051] Turning to FIG. 4E, illustrated is the well system 400 of FIG. 4D after the first fracturing port cover 215a has been moved to the second position exposing the one or more fracturing ports 275a, and the first rotating fracturing valve 255a has been moved to the second wellbore casing 270 closed position. Accordingly, the first fracturing zone of interest 295a is isolated from any zones there below using the first rotating fracturing valve 255a. The first fracturing port cover 215a and first rotating fracturing valve 255a may be moved from their respective first positions to their respective second positions using the first fracturing port actuator 220a and first rotating fracturing valve actuator 260a, respectively. Moreover, the first fracturing port actuator 220a and first rotating fracturing valve actuator 260a may be activated by the fracturing port cover

electronics 225a and rotating fracturing valve electronics 262a, respectively, based upon any of the criteria discussed above, among other criteria.

[0052] Turning to FIG. 4F, illustrated is the well system 400 of FIG. 4E after fracturing the first zone of interest 295a. Ultimately, the fracturing of the first zone of interest 295a introduces fractures 420 within the subterranean formation 290 proximate the fracturing ports 275a. Those skilled in the art understand the process of fracturing the first zone of interest 295a, including subjecting the exposed first zone of interest 295a to high pressure fluid, which may or may not contain proppant therein.

[0053] Turning to FIG. 4G, illustrated is the well system 400 of FIG. 4F after the optional step of moving the first and second port covers 215a, 215b to their respective third positions, such that the screen regions of the first and second port covers 215a, 215b are over the one or more fracturing ports 275a, 275b, respectively. Accordingly, the screen regions of the first and second port covers 215a, 215b hold the proppant within the formation 290.

[0054] While not discussed in detail above, the first and second downhole fracturing tool assemblies 210a, 210b may be operated as a flow restrictor, such as an inflow control device (ICD), autonomous inflow control device (AICD), or autonomous inflow control valve (AICV). Accordingly, after fracturing, and during or after production, the first and second downhole fracturing tool assemblies 210a, 210b may be used to control the production from the first and second fracturing zones of interest 295a, 295b. For example, not only can the first and second downhole fracturing tool assemblies 210a, 210b completely close one or both of the first and second fracturing zones of interest 295a, 295b, in certain other embodiments the first and second downhole fracturing tool assemblies 210a, 210b may squeeze the production from one or both of the first and second fracturing zones of interest 295a, 295b. Furthermore, as this process may occur many months if not years after fracturing the first and second fracturing zones of interest 295a, 295b, the second fluid flow power sources 235a, 235b may be used to provide power to the first and second downhole fracturing tool assemblies 210a, 210b.

[0055] Turning to FIGs. 5A-5G, illustrated are schematic views of one embodiment for fracturing a well system 500, the well system 500 similar in many respects to the well system 200a discussed above with regard to FIG. 2A. Accordingly, like reference numbers have been used to indicate similar, if not identical, features. The well system 500 differs, for the most part, from the well system 400 of FIGs. 4A-4G, in that the well system 500 does not include the first

and second downhole zonal isolation assemblies 250a, 250b. Accordingly, the well system 500 may be fractured in a heel to toe order.

[0056] With initial reference to FIG. 5A, the method begins with the first and second fracturing port covers 215a, 215b in the first position sealing the one or more fracturing ports 275a, 275b. This position of the first and second fracturing port covers 215a, 215b may be similar to the run-in-hole position for the downhole fracturing tool assemblies 210a, 210b.

[0057] Turning to FIG. 5B, illustrated is the well system 500 of FIG. 5A after beginning the fracturing process of the first fracturing zone of interest 295a. As shown, the first fracturing port cover 215a has been moved to the second position exposing the one or more fracturing ports 275a, while the second fracturing port cover 215b remains in the first position sealing the one or more fracturing ports 275b. Accordingly, the first fracturing zone of interest 295a is isolated from the second fracturing zone of interest using the second fracturing port cover 215b.

[0058] Turning to FIG. 5C, illustrated is the well system 500 of FIG. 5B after fracturing the first zone of interest 295a. Ultimately, the fracturing of the first zone of interest 295a introduces fractures 510 within the subterranean formation 290 proximate the fracturing ports 275a. Those skilled in the art understand the process of fracturing the first zone of interest 295a, including subjecting the exposed first zone of interest 295a to high pressure fluid, which may or may not contain proppant therein.

[0059] Turning to FIG. 5D, illustrated is the well system 500 of FIG. 5C after the optional step of moving the first fracturing port cover 215a back to the first position sealing the one or more fracturing ports 275a. In another embodiment, the first fracturing port cover 215a could be moved to the third position, such that the screen region is over the one or more fracturing ports 275a, thereby holding proppant within the formation 290. In yet another embodiment, the first fracturing port cover 215a could remain in the second position exposing the one or more fracturing ports 275a.

[0060] Turning to FIG. 5E, illustrated is the well system 500 of FIG. 5D after the second fracturing port cover 215b has been moved to the second position exposing the one or more fracturing ports 275b. Accordingly, the second fracturing zone of interest 295b is isolated from the first fracturing zone of interest 295a using the first fracturing port cover 215a.

[0061] Turning to FIG. 5F, illustrated is the well system 500 of FIG. 5E after fracturing the second zone of interest 295b. Ultimately, the fracturing of the second zone of interest 295b

introduces fractures 520 within the subterranean formation 290 proximate the fracturing ports 275b. Those skilled in the art understand the process of fracturing the second zone of interest 295b, including subjecting the exposed second zone of interest 295b to high pressure fluid, which may or may not contain proppant therein.

[0062] Turning to FIG. 5G, illustrated is the well system 500 of FIG. 5F after the optional step of moving the first and second port covers 215a, 215b to their respective third positions, such that the screen regions of the first and second port covers 215a, 215b are over the one or more fracturing ports 275a, 275b, respectively. Accordingly, the screen regions of the first and second port covers 215a, 215b hold the proppant within the formation 290.

[0063] Aspects disclosed herein include:

A. A downhole fracturing tool assembly, the downhole fracturing tool assembly including: 1) a fracturing port cover coupleable to an interior of a wellbore casing having one or more fracturing ports therein; 2) a fracturing port cover actuator coupled to the fracturing port cover, the fracturing port cover actuator operable to move the fracturing port cover between a first position sealing the one or more fracturing ports from an interior of the wellbore casing and a second position exposing the one or more fracturing ports to the interior of the wellbore casing; and 3) fracturing port cover electronics coupled to the fracturing port cover actuator proximate the fracturing port cover, the fracturing port cover electronics operable to activate the fracturing port cover actuator.

B. A well system, the well system including: 1) a wellbore extending through one or more subterranean formations; 2) wellbore casing located within the wellbore, the wellbore casing having one or more fracturing ports located at a fracturing zone of interest; and 3) a downhole fracturing tool assembly positioned proximate the fracturing zone of interest, the downhole fracturing tool assembly including: a) a fracturing port cover coupleable to an interior of the wellbore casing proximate the one or more fracturing ports; b) a fracturing port cover actuator coupled to the fracturing port cover, the fracturing port cover actuator operable to move the fracturing port cover between a first position sealing the one or more fracturing ports from an interior of the wellbore casing and a second position fully exposing the one or more fracturing ports to the interior of the wellbore casing; and c) fracturing port cover electronics coupled to the fracturing port cover actuator proximate the fracturing port cover, the fracturing port cover electronics operable to activate the fracturing port cover actuator.

C. A method for fracturing a well system, the method including: 1) positioning a downhole fracturing tool assembly within a wellbore extending into one or more subterranean formations, the downhole fracturing tool assembly located in a wellbore casing and proximate one or more fracturing ports located at a fracturing zone of interest of the wellbore casing, the downhole fracturing tool assembly including; a) a fracturing port cover coupled to an interior of the wellbore casing proximate the one or more fracturing ports; b) a fracturing port cover actuator coupled to the fracturing port cover, the fracturing port cover actuator operable to move the fracturing port cover between a first position sealing the one or more fracturing ports from an interior of the wellbore casing and a second position fully exposing the one or more fracturing ports to the interior of the wellbore casing; and c) fracturing port cover electronics coupled to the fracturing port cover actuator proximate the fracturing port cover, the fracturing port cover electronics operable to activate the fracturing port cover actuator; 2) moving the fracturing port cover between the first position sealing the one or more fracturing ports from the interior of the wellbore casing and the second position fully exposing the one or more fracturing ports to the interior of the wellbore casing using the fracturing port actuator; and 3) fracturing the fracturing zone of interest with the fracturing port cover in the second position.

[0064] Aspects A, B, and C may have one or more of the following additional elements in combination: Element 1: wherein the fracturing port cover is a sleeve lining at least a portion of the interior of the wellbore casing. Element 2: wherein the sleeve is a sliding sleeve operable to linearly slide along a length of the wellbore casing. Element 3: wherein the sleeve is a rotating sleeve operable to rotate about the interior of the wellbore casing. Element 4: wherein the sleeve has a fully closed region for sealing the one or more fracturing ports and a screen region for holding proppant within a formation proximate the one or more fracturing ports. Element 5: wherein the fracturing port cover actuator is operable to move the fracturing port cover between the first position, the second position, and a third position with the screen region holding proppant within the formation proximate the one or more fracturing ports. Element 6: wherein the fracturing port cover is a rotating ball valve movable between the first position and the second position. Element 7: further including a power source coupled to the fracturing port cover electronics proximate the fracturing port cover, the power source operable to power the fracturing port cover electronics. Element 8: wherein the power source is a downhole battery source. Element 9: wherein the downhole battery source is a first power source, and further

including a second fluid flow power source coupled to the fracturing port cover electronics. Element 10: wherein the second fluid flow power source is a turbine generator. Element 11: further including a fluid port for coupling fractures proximate the one or more fracturing ports and the fluid flow power source. Element 12: wherein the fracturing port cover is operable to redirect fluid to the fluid flow power source via the fluid port. Element 13: wherein the fracturing port cover electronics are programmed to activate the fracturing port cover actuator. Element 14: wherein the fracturing port cover electronics are programmed to activate the fracturing port cover actuator based upon changes in at least one of time, temperature, pressure or flow. Element 15: wherein the fracturing port cover electronics are programmed to activate the fracturing port cover actuator based upon a signal encoded on the wellbore casing or within fluid within the wellbore casing. Element 16: wherein the fracturing port cover electronics are programmed to activate the fracturing port cover actuator based upon a signal received from a drop ball or drop plug traversing down the wellbore casing. Element 17: wherein the fracturing port cover is a sleeve lining at least a portion of the interior of the wellbore casing. Element 18: wherein the sleeve is a sliding sleeve operable to linearly slide along a length of the wellbore casing. Element 19: wherein the sleeve is a rotating sleeve operable to rotate about the interior of the wellbore casing. Element 20: wherein the sleeve has a fully closed region for sealing the one or more fracturing ports and a screen region for holding proppant within a formation proximate the one or more fracturing ports. Element 21: wherein the fracturing port cover actuator is operable to move the fracturing port cover between the first position, the second position, and a third position with the screen region holding proppant within the formation proximate the one or more fracturing ports. Element 22: wherein the downhole fracturing tool assembly further includes a battery power source coupled to the fracturing port cover electronics proximate the fracturing port cover, the battery power source operable to power the fracturing port cover electronics. Element 23: wherein the downhole battery source is a first power source, and further including a second turbine power source coupled to the fracturing port cover electronics. Element 24: wherein the downhole fracturing tool assembly further includes a fluid port for coupling fractures proximate the one or more fracturing ports and the turbine power source. Element 25: wherein the downhole fracturing tool assembly is a first downhole fracturing tool assembly positioned proximate a first fracturing zone of interest, and further including a second downhole fracturing tool assembly positioned within the wellbore casing

downhole of the first downhole fracturing tool assembly and proximate a second different fracturing zone of interest. Element 26: further including a downhole zonal isolation assembly positioned downhole of the downhole fracturing tool assembly, the downhole zonal isolation assembly including a rotating fracturing valve positioned within the wellbore casing, the rotating fracturing valve operable to move from a first wellbore casing open position to a second wellbore casing closed position. Element 27: wherein the fracturing port cover is a sleeve having a fully closed region for sealing the one or more fracturing ports and a screen region for holding proppant within a formation proximate the one or more fracturing ports, and further including moving the fracturing port cover from the second position to a third position with the screen region holding proppant within the formation proximate the one or more fracturing ports after fracturing the fracturing zone of interest.

[0065] 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.