A technique involves injection of a fluid into a subterranean region. An injection string is provided with a plurality of injection devices positioned to enable fluid injection into the subterranean region when the system is deployed in a wellbore. Each injection device comprises a base pipe and a surrounding structure mounted over the base pipe. The surrounding structure is designed to create a desired injection fluid flow path from a base pipe radial flow opening to an outlet of the surrounding structure. Various features are incorporated into or used in cooperation with the surrounding structure to facilitate system functionality and to increase the life of the system.
SYSTEM AND METHOD FOR CONTROLLING FLUID INJECTION IN A WELL

BACKGROUND

[0001] A variety of systems and methodologies are used to inject fluid into subterranean regions. For example, an injection string can be deployed downhole into a wellbore to deliver a desired injection fluid into the surrounding reservoir of an oil or gas well. Injection fluid is delivered downhole through the injection string and routed radially outward through openings in the injection string at the desired injection location.

[0002] The injection string may comprise a base pipe with injection devices mounted on the base pipe at specific locations along the base pipe. The injection fluid is directed radially outward through the base pipe and into the injection devices which, in turn, control the fluid flow to the surrounding reservoir. Existing injection devices are attached to the base pipe with elastomer seals and/or welding, but such attachment methods can have detrimental effects with respect to system temperature sensitivity, potential for corrosion, loss of strength and reduced system life. Existing injection devices also tend to have relatively large cross sections and tend to be constructed with expensive, exotic materials to resist the corrosive downhole environment. As a result, the functionality of the system is reduced while the cost of the system is increased.

SUMMARY

[0003] In general, the present invention provides a system and method to facilitate injection of a fluid into a subterranean region. An injection string is provided with a plurality of injection devices positioned to facilitate fluid injection when the system is deployed in a wellbore. Each injection device comprises a base pipe and a surrounding structure mounted over the base pipe. The surrounding structure is designed to create a desired injection fluid flow path from a base pipe radial flow opening to an outlet of the surrounding structure. Various features are incorporated into or used in cooperation with the surrounding structure to facilitate system functionality and to increase the life of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Certain embodiments of the invention will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements, and:

[0005] FIG. 1 is a schematic front elevation view of a well system having an injection string deployed in a wellbore, according to an embodiment of the present invention;

[0006] FIG. 2 is a sectional view of a portion of a surrounding injection structure mounted on a base pipe, according to an embodiment of the present invention;

[0007] FIG. 3 is a partial, cross-sectional view taken generally along line 3-3 of FIG. 2, according to an embodiment of the present invention;

[0008] FIG. 4 is a sectional view of a portion of another surrounding injection structure mounted on a base pipe, according to an alternate embodiment of the present invention;

[0009] FIG. 5 is a partial, cross-sectional view taken generally along line 5-5 of FIG. 4, according to an alternate embodiment of the present invention;

[0010] FIG. 6 is a sectional view of a portion of another surrounding injection structure mounted on a base pipe, according to an alternate embodiment of the present invention;

[0011] FIG. 7 is a partial, cross-sectional view taken generally along line 7-7 of FIG. 6, according to an alternate embodiment of the present invention; and

[0012] FIG. 8 is a partial, sectional view of an embodiment of a tool that can be used to move seal rings into sealing engagement between the base pipe and the surrounding structure, according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0013] In the following description, numerous details are set forth to provide an understanding of the present invention. However, it will be understood by those of ordinary skill in the art that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0014] The present invention relates to a system and method used in facilitating and controlling the injection of fluid into a subterranean region. For example, the system and method can be used to control the injection of fluids into the subterranean reservoir of an oil well or a gas well. The system comprises an injection string having a plurality of injection devices positioned at desired locations along the injection string to facilitate injection of fluid into a wellbore and into the surrounding subterranean region, e.g., reservoir, along a length of the injection string. The design of the injection devices provides the overall injection string with a relatively small cross-section characterized by a low ratio of maximum outside diameter to base pipe outside diameter. The injection string construction also enables use of lower-cost materials while avoiding expensive, exotic materials even in high-temperature and high injection pressure well applications.

[0015] In one embodiment, the injection devices are formed with all metal construction that eliminates the needs for elastomer seals and other expensive materials and components. For example, seals can be formed along a base pipe with non-elastomer rings, such as metal rings that may be in the form of metal, wedge-shaped, compressed seal rings. The lack of the elastomer seals also avoids limitations with respect to elevated temperatures and with respect to the lifespan of the injection string. In this same embodiment, the injection devices can be constructed without requiring welding of components to the base pipe and without requiring turning or milling of the base pipe. In some embodiments, the injection devices are provided with a removable cover that provides easy access to injection nozzles on a low pressure side of the injection nozzles.

[0016] Referring generally to FIG. 1, an example of a well system 20 is illustrated according to an embodiment of the present invention. The well system 20 comprises an injection string 22 that may be deployed downhole into a wellbore 24. By way of example, wellbore 24 may comprise a deviated wellbore section 26, e.g., a generally horizontal wellbore section; however the injection string 22 can be used in a many types of wellbores formed at a variety of orientations. In the embodiment illustrated, wellbore 24 and deviated wellbore section 26 extend through a subterranean region 28, such as an oil reservoir or a gas reservoir.

[0017] In the example illustrated, injection string 22 comprises a plurality of injection devices 30 that are used to control the injection of fluid from injection string 22 into the
surrounding subterranean region 28. The injection devices 30 are spaced from each other and positioned at desired locations along the injection string 22. The wellbore 24 may be divided into isolated sections via isolation devices 32, such as packers, to facilitate the controlled flow of injection fluid from the injection devices 30 into the surrounding subterranean region 28.

[0018] Referring generally to FIG. 2, an embodiment of one of the injection devices 30 is illustrated in partial cross-section. It should be noted that the injection device 30 is generally tubular in shape with an axis 34 extending along the center of the tubular structure. In the embodiment illustrated, injection device 30 comprises a base pipe 36 and a surrounding structure 38 mounted over the base pipe 36. One or more flow openings 40, such as radial flow openings, extend through base pipe 36 to enable flow of injection fluid from an interior of base pipe 36 into the surrounding structure 38.

[0019] The surrounding structure 38 may be constructed with a variety of components arranged in different configurations depending on the specific injection application. In the embodiment illustrated, surrounding structure 38 is constructed to create an upstream chamber 42, with respect to injection fluid flow, and a downstream chamber 44 separated by a nozzle section 46. Nozzle section 46 may comprise a nozzle 48 mounted in a flow passage 50. By way of example, nozzle 48 may be an interchangeable nozzle that is removably mounted in flow passage 50 via a suitable fastening mechanism 52, such as a threaded region.

[0020] In the example illustrated, flow passage 50 is formed in a generally axial direction through a nozzle retainer ring 54 which encircles base pipe 36, as further illustrated in FIG. 3. It should be noted that a plurality of axial, flow passages 50 can be formed through nozzle retainer ring 54 to receive corresponding nozzles 48. As illustrated, nozzle retainer ring 54 is located on one axial side of the one or more flow openings 40, while an end ring 56 is located on an opposite side of flow openings 40. A plate section 58 extends from nozzle retainer ring 54 to end ring 56 to create upstream chamber 42 for receiving injection fluid through openings 40. The plate section 58 can be attached to nozzle retainer ring 54 and end ring 56 by a variety of suitable fastening techniques, such as welding.

[0021] A flow-through ring 60 also may be mounted around base pipe 36 at a location downstream of nozzle retainer ring 54, as illustrated. Flow-through ring 60 may comprise one or more flow passages 62 that facilitate continued flow of injection fluid from downstream chamber 44 to an injection device outlet 64. In the example illustrated, flow-through ring 60 is connected to nozzle retainer ring 54 by a plurality of connector rods 66. A removable cover 68 is mounted to span from nozzle retainer ring 54 to flow-through ring 60 over downstream chamber 44, thereby defining the downstream chamber.

[0022] Removable cover 68 is attached to nozzle retainer ring 54 and/or flow-through ring 60 by fasteners 70 which may be in the form of bolts, screws, threads or other suitable fasteners. The fastener 70 can be released to remove cover 68 and to provide access to nozzles 48 on a low pressure side of nozzle section 36 and nozzles 48. In some embodiments, removable cover 68 can be designed as a slidable cover that, for example, slidingly engages flow-through ring 60 to permit adjustments to the size of downstream chamber 44. The length of cover 68 spanning downstream chamber 44 can be selected to avoid or limit the erosion of components due to the discharge of injection fluid from nozzles 48. Adjustments to the size of downstream chamber 44 can be accommodated by slidably engaging connector rods 66 with nozzle retainer ring 54 or flow-through ring 60. With respect to FIG. 2, it should be noted that a portion of removable cover 68 has been cut out to illustrate the position of connecting rods 66.

[0023] A screen 72, such as a sand screen, may be positioned over outlet 64. In the example illustrated, screen 72 is connected with flow-through ring 60 by a connector plate 74 that may be fastened to screen 72 and flow-through ring 60 by a suitable fastener mechanism, such as welding. Screen 72 is designed and positioned to prevent the back flow of sand and other particulates into injection device 30.

[0024] In the embodiment illustrated, surrounding structure 38 is sealed with respect to base pipe 36 via seal rings 76 formed from a non-elastomer material. For example, seal rings 76 may be constructed as metal seal rings that are movable to enable insertion between base pipe 36 and the components of surrounding structure 38. In one example, seal rings 76 are inserted between base pipe 36 and surrounding structure 38 on opposite sides of flow openings 40. In the embodiment illustrated, seal rings 76 are sealably engaged between base pipe 36 and nozzle retainer ring 54 and between base pipe 36 and end ring 56. The seal rings 76 may be formed of a ductile, metal material having a leading wedge 78 to facilitate insertion of the seal rings 76 between base pipe 36 and surrounding structure 38. The leading wedge 78 can be oriented to engage a corresponding chamber region 79 of the cooperating component of surrounding structure 38. In some applications, the leading wedge sections 78 of separate seal rings 76 can be oriented in opposite directions to facilitate the maintenance of surrounding structure 38 at a desired axial position with respect to base pipe 36. Additionally, seal rings 76 can be inserted to form the desired seals at various stages of construction during formation of surrounding structure 38.

[0025] In operation, injection fluid is pumped down through injection string 22 along the interior of the base pipe 36. The lower end of base pipe 36 is closed which forces the injection fluid to flow radially outward through the flow openings 40 of each injection device 30. From flow openings 40, the injection fluid enters upstream chamber 42 and is directed axially along passages 50, through nozzles 48, and into downstream chamber 44. The injection fluid flows through downstream chamber 44 and along flow passages 62 until exiting the injection device 30 via outlet 64. In the example illustrated, the injection fluid flows outwardly through screen 72, into the corresponding isolated wellbore section, and on into the surrounding subterranean region.

[0026] Another embodiment of injection device 30 is illustrated in FIG. 4. In this embodiment, upstream chamber 42 is formed in nozzle retainer ring 54, and downstream chamber 44 is formed between end ring 56 and nozzle retainer ring 54. Injection fluid flows from the interior of base pipe 36, through flow opening 40, and into upstream chamber 42. The injection fluid then flows through nozzle 48 in a first direction, e.g. a first axial direction, and into downstream chamber 44 between nozzle retainer ring 54 and end ring 56, as illustrated by fluid flow arrows 80. The flow of injection fluid is then reversed such that the fluid flows in another direction, e.g. an opposite axial direction, through one or more passages 82 formed through nozzle retainer ring 54, as further illustrated in FIG. 5. The injection fluid then flows past flow-through ring 60 and out of injection device 30 through outlet 64.
In the embodiment illustrated in FIGS. 4 and 5, removable cover 68 is mounted between nozzle retainer ring 54 and end ring 56 generally at an end of the injection device 30. Cover 68 may again be removably mounted to nozzle retainer ring 54 by suitable fasteners 70. Additionally, slideable connector rods 66 may be connected between nozzle retainer ring 54 and end ring 56 to enable adjustment of the size of downstream chamber 44. Nozzle 48 and removable cover 68 are positioned such that removal of cover 68 provides easy access to the one or more nozzles 48 on a low-pressure side of the nozzles. If interchangeable nozzles are employed, removable cover 68 provides easy access for interchanging the nozzles. Plate 58 can be used to connect nozzle retainer ring 54 and flow-through ring 60 and may be attached to the rings 54, 60 by a suitable fastening mechanism, such as welding.

In this embodiment, the use of elastomer seals and welds to the base pipe 36 also can be avoided. Non-elastomer seal rings 76, such as metal seal rings, are used to seal between base pipe 36 and surrounding structure 38. In the example illustrated, seal rings 76 are used on opposite sides of base pipe flow openings 40 to form seals between nozzle retainer ring 54 and the base pipe 36. The wedge portions 78 of seal rings 76 can be oriented in opposed directions, e.g., facing each other, to form a secure seal between the base pipe and the surrounding structure.

Another embodiment of injection device 30 is illustrated in FIG. 6. In this embodiment, the components of surrounding structure 38 are arranged similarly to those of the embodiment illustrated in FIG. 4. However, a variety of changes can be incorporated, including the use of additional passages 82 further illustrated in the cross-sectional view of FIG. 7. Furthermore, the length of removable cover 68 can be shortened by incorporating an erosion resistant surface or plate 84 into end ring 56. The erosion resistant plate 84 is positioned so that injection fluid exiting nozzle 48 is directed against the erosion resistant plate before being redirected through passages 82.

In the embodiment of FIG. 6, additional flow openings 40 are provided through base pipe 36 to provide a greater flow area for injection fluids flowing from an interior of base pipe 36 to upstream chamber 42. Additionally, the fastener 70 used to removably attach cover 68 between nozzle retainer ring 54 and end ring 56 may comprise a threaded region 86 by which removable cover 68 is threadably engaged with nozzle retainer ring 54 and/or end ring 56. Similar to the embodiments described above, the configuration of surrounding structure 38 in the embodiment of FIG. 6 also enables a low profile injection device 30 that requires no elastomers. Although the surrounding structure 38 can be attached and sealed to base pipe 36 by welds 88, seal rings 76 also can be employed, as described above.

In any of the embodiments described above, one or more of seal rings 76 can be moved in an axial direction and forced between base pipe 36 and the surrounding structure 38 in a manner that ensures sealing even if the base pipe 36 has non-circular regions or if other abnormalities exist between base pipe 36 and the surrounding structure 38. Each seal ring 76 can be moved in an axial direction such that portions of the movable seal ring move farther in the axial direction than other portions of the seal ring to ensure formation of a seal even if irregularities exist between the base pipe 36 and the surrounding structure 38.

As illustrated in FIG. 8, a tool 90 can be used to move selected seal rings 76 in an axial direction such that portions of the seal ring 76 move farther axially then other portions. In other words, an end face 92 of the seal ring 76 does not remain in the same plane, thus allowing the seal ring 76 to compensate for a non-circular base pipe or other irregularities between the base pipe 36 and surrounding structure 38. Although a variety of tools 90 can be employed, one example comprises a base structure 94, such as a common cylinder ring, to which a plurality of individual pistons 96 are individually coupled for movement against the face 92 of seal ring 76. Pistons 96 may be actuated hydraulically, electrically, or by other suitable actuation mechanisms. By clamping or otherwise securing base structure 94 around the base pipe 36 (at least temporarily), actuation of individual pistons 96 forces seal ring 76 to move axially until portions of the seal ring move a sufficient axial distance to secure a seal along the entire seal region between base pipe 36 and surrounding structure 38. By way of example, the wedge portion 78 of seal ring 76 should move farther into the mating chamfer region 79 where a non-circular base pipe has a smaller diameter.

The overall well system 20 can be constructed in a variety of configurations for use in many environments and applications. For example, various types of base pipe structures and injection device structures can be employed. Additionally, the number of injection devices, the length of the injection region, and the orientation of the wellbore can vary from one application to another. The injection devices also may incorporate a variety of components in different arrangements depending on the injection fluid and operational or environmental factors. The injection fluid may comprise a variety of liquids, including water, or gasses depending on the environment and injection parameters. Furthermore, the base pipe and the surrounding structure can be formed with a variety of materials. In some embodiments, the base pipe and all components of the surrounding structure are formed from metals. The metal seal rings and the removable covers can be formed in a variety of sizes and configurations.

Accordingly, although only a few embodiments of the present invention have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this invention. Such modifications are intended to be included within the scope of this invention as defined in the claims.

What is claimed is:

1. A system for use in a wellbore to inject a fluid, comprising:
   an injection string having a plurality of injection devices to inject fluid into a surrounding subterranean region, each injection device comprising:
   a base pipe; and
   a surrounding structure mounted over the base pipe to create an upstream chamber and a downstream chamber separated by a nozzle that restricts flow of injection fluid, the base pipe comprising a radial flow opening positioned to enable flow from an interior of the base pipe to the upstream chamber, the surrounding structure being sealed to the base pipe with a metal seal ring.

2. The system as recited in claim 1, wherein the surrounding structure is sealed to the base pipe with a plurality of metal seal rings.
3. The system as recited in claim 1, wherein the nozzle is removable.

4. The system as recited in claim 3, wherein the surrounding structure further comprises a removable cover positioned to enable access to the nozzle on a low-pressure side of the nozzle.

5. The system as recited in claim 1, wherein all components of the base pipe and the surrounding structure are formed of metal.

6. The system as recited in claim 1, wherein the base pipe is free of welds between the base pipe and the surrounding structure.

7. The system as recited in claim 1, wherein the nozzle is mounted in a nozzle retainer ring having an axial passage extending from the upstream chamber to the nozzle.

8. The system as recited in claim 1, wherein the nozzle is mounted in a nozzle retainer ring, the nozzle conducting flow of injection fluid in a first direction, the nozzle retainer ring further comprising an axial passage positioned to conduct flow of the injection fluid in a second direction.

9. The system as recited in claim 4, wherein the removable cover is slidable to enable adjustment of the size of the downstream chamber.

10. A method, comprising:
    providing a base pipe with a radial opening;
    constructing a surrounding structure with an upstream chamber, a downstream chamber, a nozzle section positioned between the upstream chamber and the downstream chamber, and an outlet in communication with the downstream chamber;
    mounting the surrounding structure around the base pipe so the radial opening is in communication with the upstream chamber; and
    sealing the surrounding structure with respect to the base pipe via at least one movable ring formed from a non-elastomer material.

11. The method as recited in claim 10, wherein sealing comprises sealing via a movable metal ring.

12. The method as recited in claim 11, wherein sealing comprises sealing via a plurality of movable metal rings.

13. The method as recited in claim 10, wherein constructing comprises removably mounting a nozzle in the nozzle section.

14. The method as recited in claim 10, wherein constructing comprises positioning a removable cover at a location to provide access to the nozzle section on a low-pressure side of the nozzle section.

15. The method as recited in claim 10, further comprising moving the base pipe and the surrounding structure downhole into a wellbore; and injecting a treatment fluid into the surrounding subterranean region through the outlet.

16. The method as recited in claim 10, further comprising using a tool to force the at least one movable ring in an axial direction such that portions of the at least one movable ring move farther in the axial direction than other portions to ensure a seal in a non-circular region of the base pipe.

17. A system, comprising:
    an injection string having a plurality of injection devices to inject fluid into a surrounding subterranean region, each injection device comprising:
    a base pipe; and;
    a surrounding structure mounted over the base pipe to create an upstream chamber and a downstream chamber separated by a nozzle that restricts flow of injection fluid, the base pipe comprising a radial flow opening positioned to enable flow from an interior of the base pipe to the upstream chamber, the surrounding structure further comprising a removable cover positioned to enable access to the nozzle on a low-pressure side of the nozzle.

18. The system as recited in claim 17, further comprising at least one metal seal ring position to form a seal between the base pipe and the surrounding structure without elastomers.

19. The system as recited in claim 17, wherein the nozzle is removable.

20. The system as recited in claim 17, wherein the removable cover enables adjustment of the size of the downstream chamber.

21. A method, comprising:
    providing a base pipe with a radial opening;
    constructing a surrounding structure with an upstream chamber, a downstream chamber, a nozzle section positioned between the upstream chamber and the downstream chamber, and an outlet in communication with the downstream chamber;
    mounting the surrounding structure around the base pipe so the radial opening is in communication with the upstream chamber; and
    utilizing a removable cover on the surrounding structure to provide access to the nozzle section on a low-pressure side of the nozzle section.

22. The method as recited in claim 21, further comprising sealing the surrounding structure with respect to the base pipe solely with one or more movable metal seal rings.

23. The method as recited in claim 21, wherein utilizing the removable cover comprises attaching the removable cover with a plurality of fasteners.

24. The method as recited in claim 21, further comprising removing the removable cover and subsequently removing a nozzle from the nozzle section.

25. The method as recited in claim 21, further comprising moving the base pipe and the surrounding structure downhole into a wellbore; and injecting a treatment fluid into the surrounding subterranean region through the outlet.