A method and apparatus for use in hydrocarbon exploration. The method and apparatus improve downhole flow back control in oil and/or gas wells by controlling fluid entry into the well bore. Either a single limited entry opening or a small cluster of limited entry openings is provided in a well liner or casing and cement sheath allowing fluid communication between a region of a well bore and a subterranean reservoir. The method also uses the limited entry opening or the cluster during an injection treatment of the subterranean reservoir to control fluid entry. The method also provides a proppant flow back treatment following the injection treatment of the subterranean reservoir.
Figure 2 (Prior Art)

Figure 3 (Prior Art)
Figure 4
(Prior Art)
Figure 12
1300

Providing either a single limited entry opening or a small cluster of limited entry openings in a well liner or casing and cement sheath allowing fluid communication between a region of a well bore of about 2 feet in length and a subterranean reservoir

1310

Controlling fluid entry using the single limited entry opening or small cluster of limited entry openings during an injection treatment of the subterranean reservoir

1320

Providing a proppant flow-back treatment following the injection treatment of the subterranean reservoir

1330

Isolating the single limited entry opening or small cluster of limited entry openings from other areas of the subterranean reservoir

1340

Figure 13
Providing either a single limited entry opening or a small cluster of limited entry openings in a well liner or casing and cement sheath allowing fluid communication between a region of a well bore of about 2 feet in length and a subterranean reservoir

Controlling fluid entry using the single limited entry opening or small cluster of limited entry openings during sequential injection treatments of the subterranean reservoir

Providing a proppant flow-back treatment following each of the sequential injection treatments of the subterranean reservoir

Isolating the single limited entry opening or small cluster of limited entry openings from other areas of the subterranean reservoir, wherein each limited entry opening in a vertical well implementation has the limited entry opening aligned substantially vertically, each limited entry opening in a deviated well implementation having an axis of a region of the well bore deviated through an angle of about $\theta$ below a horizontal direction has the limited entry opening aligned substantially at an angle of about \[ \frac{\pi - \theta}{2} \] from the axis direction, and each cluster of limited entry opening in a horizontal well implementation has the limited entry opening aligned substantially radially.

Figure 14
Providing either a single fluid entry opening or a small cluster of limited entry openings, allowing fluid communication between a region of a well bore about 2 feet in length and a subterranean reservoir 1510

Controlling fluid entry using the fluid entry opening or cluster during an injection treatment of the subterranean reservoir 1520

Providing a proppant flow-back treatment following the injection treatment of the subterranean reservoir 1530

Isolating the single fluid entry opening or cluster from other areas of the subterranean reservoir 1540

Providing the single fluid entry opening or cluster extending through a well casing and a cement sheath (and, optionally, into at least a portion of the subterranean reservoir) 1550

Providing the single fluid entry opening or cluster formed using at least one component disposed in a casing string 1560

Providing the limited fluid entry opening or cluster after a well casing is in place downhole (using, optionally, at least one of slick-line methods, wireline methods, coiled tubing methods, jointed tubing methods, and jointed pipe methods inside a casing string) [using, optionally, at least one of shape-charge perforating methods, hydrajetting methods, hydrojetting methods, and methods comprising chemical dissolution of a material {using, optionally, at least one of hydrajetting perforating and hydrajetting slouting}] 1570

Figure 15
DOWNHOLE FLOW-BACK CONTROL FOR OIL AND GAS WELLS BY CONTROLLING FLUID ENTRY

FIELD OF THE INVENTION

[0001] The present invention relates generally to a method and apparatus utilized in hydrocarbon exploration. More specifically, the present invention relates to a method and apparatus for improving downhole flow-back control in oil and/or gas wells by controlling fluid exiting the wellbore during injection of a treatment fluid and entering the wellbore during treating fluid clean-up or production of reservoir fluids.

BACKGROUND OF THE INVENTION

[0002] For many oil and/or gas wells, there are problems related to the inflow of various solids into the wellbore from the formation. In some cases, formation particles are being transported into the wellbore by the inflow of the reservoir fluid and/or fluids and/or gases. The transportation of formation particles into the wellbore is particularly likely if the formation rock particles are not well cemented together and/or if the pressure differential between the wellbore pressure and the reservoir pressure becomes relatively high. Other problem cases involve the flow-back of granular solids that have been pumped into the formation by some treatment process, such as proppant placed during a hydraulic fracturing treatment. During the process of placing a gravel pack for sand control purposes, granular solids may be pumped into an annular space between the formation and a liner, or into an annulus between the well casing and a screen or solid liner inside that casing. Flow-back of these grains during production can also be a problem.

[0003] Many conventional methods have been developed to overcome these problems, but lower cost methods and/or more effective methods are still needed, particularly for oil-producing and gas-producing wells. In some of these cases, as well as in many other reservoirs, there can be both downhole and surface facility problems resulting from the flow-back of either formation solids or solids that were placed downhole during a pumping operation, such as during a hydraulic fracturing process, a frac-pack operation, a gravel pack completion, and the like.

[0004] One of the recurring problems with conventional technologies is that an operator cannot afford the cost of many of the most effective available treatment methods. This tends to be particularly the case for many operations that involve some form of hydraulic fracturing in the well completion and/or worksite plan. In such cases, the control of flow-back of formation particles and/or injected solids such as fracturing proppant and/or gravel pack solids may only be applied in the near-wellbore region. In many cases, the need for control of flow-back will be most urgent in a zone that is in a range of about one or more inches to about one or more feet within the wellbore. In some cases, this zone will be the only region where control of flow-back is needed, if that need for control of flow-back can be met.

[0005] In many conventional well completions, particularly those using shape-charge perforating techniques and/or open-hole hydraulic fracturing methods, the operator does not have substantially complete control over where a pumped fluid is entering the reservoir (i.e., exiting the wellbore) at substantially all times during an injection operation. Because of this, it is often necessary for the operator to use a flow-back control method and/or a chemical treatment on substantially all fluid stages in which carry solids injected into the reservoir during the pumping operation to help guarantee that all near-wellbore zones are properly treated at the conclusion of the well completion job placement. Additionally, there is seldom a cost-effective method for controlled injection of such a treatment and/or chemical subsequent to injection of the solids but before fluid is produced back through these solids that could undesirably carry the solid back into the wellbore.

[0006] Conventional completions may be classified generally in two groups, (1) completions of producing zone(s) using a cemented casing fully extending through the producing zone(s), accounting for about 80% to about 90% of completions of producing zone(s), and (2) "open" completions of producing zone(s) done using a non-cemented casing or no casing at all through the producing zone(s), accounting for about 10% to about 20% of oil and gas well completions. Generally, most wells of either category will have a cemented casing above the producing interval. Although some wellbores may be completed with both types of conventional completions employed at different locations within the wellbore, typically each individual type of producing zone is usually completed with a separate operation and/or technique. These conventional completions may be vertical, horizontal, and/or deviated to some extent.

[0007] For producing zone(s) completed using cemented casing(s), nearly all are conventionally completed using shape-charge perforation techniques to create communication between reservoir rock and the wellbore. In extreme cases where an operator desires to control treatment fluid entry from the wellbore to the reservoir rocks, the operator may use a conventional "limited entry" technique where the number of perforations is limited in quantity and in size so that a fluid pressure differential can be created across the holes in the casing and hydraulically induced cracks within the rock during an injection treatment. However, only if this conventional "limited entry" technique is applied in a very extreme and very expensive manner will there be any assurance that substantially all such holes will be accepting injected fluid throughout substantially the entire injection period. Furthermore, even if such a conventional "limited entry" technique is applied in this very extreme and very expensive manner, it is proven that not all such entry points are adequately accepting fluid at the final stages of the injection period.

[0008] For example, as shown in FIG. 1, a conventional "limited entry" technique may involve introducing a limited number of perforations 110 of a limited size throughout a length 120 of between about 10 feet (ft) and about 100 feet of a cemented casing 130 in a wellbore 140 in a producing formation 150. The number and resultant opening size sizes chosen for the perforations 110 may depend on the flow rate achievable during the injection stage of a treatment. Ideally, a perforation 110 size should be small enough so that a pressure differential can be attained when the flow rate is at the designed maximum flow rate, which is such that the pressure differential is larger than the maximum pressure difference between the wellbore 140 and the producing
Pressure differentials of 200 to 500 psi are commonly used, but may approach 1,000 psi differential pressure.

FIG. 2 shows an idealized but sometimes unrealistic view of an hydraulic fracture 250 created by the conventional “limited entry” technique shown in FIG. 1, extending outward substantially perpendicularly from the cemented casing 130. FIG. 3 shows a cross-sectional view, taken along line III-III, of the idealized but possibly unrealistic view of the hydraulic fracture 250 created by the conventional “limited entry” technique shown in FIG. 1 where all wellbore perforations are in communication with a single plane fracture extending within the reservoir. FIG. 4 shows a more realistic view of hydraulic fractures 450, 460, and 470 created by the conventional “limited entry” technique shown in FIG. 1, where the multiple substantially parallel hydraulic fractures 450, 460, and 470 at the wellbore 140 may not be communicated substantially outside the wellbore 140. One or more of the multiple substantially parallel hydraulic fractures 450, 460, and 470 at the wellbore 140 may not be accepting fluid at the end of the pumping treatment. Moreover, one or more of the multiple substantially parallel hydraulic fractures 450, 460, and 470 at the wellbore 140 may not be accepting fluid at all for most of the injection time during the job.

Moreover, there is seldom any effective post-treatment method to increase through-casing communication with hydraulic fractures, such as the multiple substantially parallel hydraulic fractures 450, 460, and 470, created by such a conventional “limited entry” technique applied in this very extreme and very expensive manner, so that produced fluid entry to the wellbore will also be limited to the same small number of small perforations. These problems severely limit the usefulness of such an extreme “limited entry” technique completion method.

For zone(s) completed with or without cemented liner(s), the gravel-pack technique, with a screen on the inside of the wellbore, is often conventionally used to control production of formation fines, and/or after a hydraulic fracturing treatment to control flow-back of injected solids. However, this gravel-pack technique is usually cost-prohibitive for low permeability reservoirs and also for many moderate permeability wells.

SUMMARY

The present invention relates generally to a method and apparatus utilized in hydrocarbon exploration. More specifically, the present invention relates to a method and apparatus for improving downhole flow-back control in oil and/or gas wells by effectively controlling fluid exit or entry into the wellbore.

In various aspects, a method is provided, the method comprising providing either a single limited entry opening or a small cluster of limited entry openings in a well liner or casing and cement sheath allowing fluid communication between a region of a wellbore of not more than about 2 feet in length and a subterranean reservoir. The method also comprises controlling fluid entry using the opening or limited entry cluster during an injection treatment of the subterranean reservoir. The method also comprises providing a formation consolidation enhancement treatment and/or a proppant flow-back treatment as part of or following the injection treatment of the subterranean reservoir.

In various other aspects, a method is provided, the method comprising providing a single limited entry opening or a small cluster of limited entry openings in a well liner or casing and cement sheath allowing fluid communication between a region of a wellbore of not more than about 2 feet in length and a subterranean reservoir. The method also comprises controlling fluid entry using the limited entry opening or the cluster during an injection treatment of the subterranean reservoir. The method also comprises providing a proppant flow-back treatment following the injection treatment of the subterranean reservoir. The method also comprises isolating the fluid entry opening or small cluster from other areas of the subterranean reservoir during the treatment injection phase.

In yet various other aspects, a method is provided, the method comprising providing either a single limited entry opening or a small cluster of limited entry openings without restriction to the shape of these openings or the special arrangement of the openings within the wellbore. This method is not limited to the creation of openings in the wellbore that provide fluid communication between a reservoir and the wellbore.

The method also comprises controlling fluid entry using a single limited entry opening or a small cluster of limited entry openings during sequential injection treatments of the subterranean reservoir at multiple locations along the wellbore at separate stages of the completion process. The method also comprises providing one or more treatments that enhance formation consolidation and/or a proppant flow-back treatment following each of the sequential injection treatments of the subterranean reservoir. In some applications, there may be a single treatment method that would serve to provide both benefits of enhancing formation consolidation and reducing proppant flow-back during treatment clean-up, formation fluid production, or both flow periods.

The method also comprises isolating either a single limited entry opening or a small cluster of limited entry openings from other areas of the subterranean reservoir, wherein each cluster of limited entry openings in a vertical well implementation has the limited entry openings aligned substantially vertically, each cluster of limited entry openings in a deviated well implementation having an axis of a region of the wellbore deviated through an angle of about θ below a horizontal direction has the limited entry openings aligned substantially at an angle of about

\[
\frac{\pi}{2} - \theta
\]

from the axis direction, and each cluster of limited entry openings in a horizontal well implementation has the limited entry openings aligned substantially radially.

The features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of the embodiments that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The following figures form part of the present specification and are included to further demonstrate certain
aspects of the present invention. The present invention may be better understood by reference to one or more of these drawings in combination with the description of embodiments presented herein.

[0020] Consequently, a more complete understanding of the present disclosure and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, in which the leftmost significant digit(s) in the reference numerals denote(s) the first figure in which the respective reference numerals appear, wherein:

[0021] FIG. 1 schematically illustrates a conventional “limited entry” technique involving introducing a limited number of perforations of a limited size throughout a length of between about 20 feet (ft) and about 100 feet of a cemented casing in a wellbore in a producing formation;

[0022] FIG. 2 schematically illustrates an idealized and unrealistic view of an hydraulic fracture created by the conventional “limited entry” technique shown in FIG. 1;

[0023] FIG. 3 schematically illustrates a cross-sectional view, taken along line III-III, of the idealized and unrealistic view of the hydraulic fracture created by the conventional “limited entry” technique shown in FIG. 1;

[0024] FIG. 4 schematically illustrates a more realistic view of multiple hydraulic fractures created by the conventional “limited entry” technique shown in FIG. 1;

[0025] FIGS. 5-8 schematically illustrate various limited entry techniques according to the present disclosure;

[0026] FIG. 9 schematically illustrates a view of an hydraulic fracture created by various of the limited entry techniques according to the present disclosure shown in FIGS. 5-8;

[0027] FIG. 10 schematically illustrates a cross-sectional view, taken along line IX-IX, of the hydraulic fracture created by various of the limited entry techniques according to the present disclosure shown in FIGS. 5-8;

[0028] FIGS. 11-12 schematically illustrate various additional limited entry techniques according to the present disclosure;

[0029] FIG. 13 schematically illustrates a method according to the present disclosure for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore;

[0030] FIG. 14 schematically illustrates another method according to the present disclosure for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore; and

[0031] FIG. 15 schematically illustrates yet another method according to the present disclosure for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore.

DETAILED DESCRIPTION

[0032] The present invention relates generally to a method and apparatus utilized in hydrocarbon exploration. More specifically, the present invention relates to a method and apparatus for improving downhole flow-back control of solids in oil and/or gas wells by controlling fluid entry into the wellbore.

[0033] Illustrative embodiments of the present invention are described in detail below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers’ specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of the present disclosure.

[0034] In various illustrative embodiments, as shown in FIGS. 5-15, for example, a method and a system for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into a wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) may comprise providing either a limited entry opening 510 (as shown in FIG. 5, for example) or a cluster 710 of not more than about five limited entry openings 710a (as shown in FIGS. 7, 8, 11 and 12, for example), allowing fluid communication between a region 520 (region 720 in FIG. 7, region 820 in FIG. 8, region 1120 in FIG. 11, and region 1220 in FIG. 12) of the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) of not more than about 2 feet in length and a subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12), controlling fluid entry using either the limited entry opening 510 or the cluster 710 during an injection treatment of the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12), as indicated schematically at 555, and providing a proppant flow-back treatment following the injection treatment of the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12), as indicated schematically at 560. Alternatively, the treatment may be a formation consolidation enhancement treatment. Additionally, the treatment may be pumped at some time after a frac pack, hydraulic fracturing treatment, or gravel pack operation.

[0035] In various illustrative embodiments, as shown in FIGS. 5-15, for example, a method and a system for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) may also comprise isolating either the limited entry opening 510 or the cluster 710 from other areas of the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12), as indicated schematically (in phantom) at 570. In various other illustrative embodiments, the region 520 (region 720 in FIG. 7, region 820 in FIG. 8, region 1120 in FIG. 11, and region 1220 in FIG. 12) of the wellbore 540 may be no more than about 10 feet in length, provided the wellbore 540 is substantially precisely vertical in the region 520 (region 720 in FIG. 7 and region 820 in FIG. 8) of the wellbore 540.

[0036] In various alternative illustrative embodiments, as shown in FIGS. 5-15, for example, a method and a system
for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) may comprise providing one or more of either the limited entry opening 510 (as shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in FIGS. 7, 8, 11 and 12, for example), allowing fluid communication between the region 520 (region 720 in FIG. 7, region 820 in FIG. 8, region 1120 in FIG. 11, and region 1220 in FIG. 12) of the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) of not more than about 2 feet in length and the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12), controlling the fluid entry using one or more of either the limited entry opening 510 or the cluster 710 during sequential injection treatments of the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12), as indicated schematically at 555, and providing the proppant flow-back treatment following each of the sequential injection treatments of the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12), as indicated schematically at 560. In these various alternative illustrative embodiments, as shown in FIGS. 5-15, for example, a method and a system for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) may also comprise isolating one or more of either the limited entry opening 510 or the cluster 710 from other areas of the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12), as indicated schematically (in phantom) at 570.

In these various alternative illustrative embodiments, as shown in FIGS. 7, 8, 11, and 12, for example, each cluster 710 of limited entry openings 710a in a vertical well implementation, as in FIGS. 7 and 8, for example, may have the limited entry openings 710a aligned substantially vertically, each cluster 710 of limited entry openings 710a in a deviated well implementation, as in FIG. 12, for example, having an axis 1260 (shown in phantom) of a region 1245 of the wellbore 1240 deviated through an angle of about \( \theta \) below a horizontal direction 1255. Similarly, in various illustrative embodiments, the horizontal well implementation, as in FIG. 11, for example, may correspond to the deviated well implementation, as in FIG. 12, for example, when the axis 1260 (shown in phantom) of the region 1245 of the wellbore 1240 has been deviated through an angle of about 0° below the horizontal direction 1255.

In various illustrative embodiments, for example, a method and a system for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) may comprise providing either the limited entry opening 510 (as shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in FIGS. 7, 8, 11 and 12, for example), with at least one limited entry opening 510, 710a having a cross-sectional area, substantially proportional to the product of a width \( W \), as indicated at 600, and a length \( L \), as indicated at 610, as shown in FIG. 6 for the limited entry opening 510, for example, with the cross-sectional area in a range of from about 0.5 square inches to about 10 square inches. In various particular illustrative embodiments, at least one limited entry opening 510, 710a may have the cross-sectional area, substantially proportional to the product of the width \( W \), as indicated at 600, and the length \( L \), as indicated at 610, as shown in FIG. 6 for the limited entry opening 510, for example, in a range of from about 2 square inches to about 6 square inches.

In various illustrative embodiments, for example, a method and a system for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) may comprise providing either the limited entry opening 510 (as shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in FIGS. 7, 8, 11 and 12, for example), with at least one limited entry opening 510, 710a having a slot having a width \( W \), as indicated at 600, in a range of from about \( \frac{3}{8} \) inch to about 1 inch. In various particular illustrative embodiments, at least one limited entry opening 510, 710a may have the slot having the width \( W \), as indicated at 600, in a range of from about \( \frac{3}{8} \) inch to about \( \frac{3}{4} \) inch.
than about 2 feet in length and the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12). In various alternative embodiments, for example, a method and a system for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) may further comprise providing either the limited entry opening 510 (as shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in Figs. 7, 8, 11, and 12, for example) extending through a well casing and a cement sheath, as indicated at 530 (well casing and cement sheath 1130 in FIG. 11 and well casing and cement sheath 1230 in FIG. 12), and into at least a portion of the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12), as indicated schematically (in phantom) at 575, allowing fluid communication between the region 520, 720, 820, 1120, 1220 of the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) of not more than about 2 feet in length and the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12).

By way of contrast with FIG. 4, which shows a more realistic view of hydraulic fractures 450, 460, and 470 created by the conventional “limited entry” technique shown in FIG. 1, where the multiple substantially parallel hydraulic fractures 450, 460, and 470 at the wellbore 140 may not all be communicated substantially outside the wellbore 140, the hydraulic fracture 950 may be communicated substantially outside the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) by virtue of being developed by either the limited entry opening 510 (as shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in Figs. 7, 8, 11 and 12, for example), which may lead to the hydraulic fracture 950, which may be substantially the only one hydraulic fracture. Furthermore, whereas one or more of the multiple substantially parallel hydraulic fractures 450, 460, and 470 at the wellbore 140 may not be accepting fluid at the end of the pumping treatment, the single hydraulic fracture 950, being the only one, may still be accepting fluid at the end of the pumping treatment. Consequently, flow-back control fluids, such as the Halliburton product EXPEDITE fracturing fluid, for example, and/or certain proppants, such as resin coated proppants (RCPs), for example, pumped at the tail end of the stimulation fluid treatment may be guaranteed to be placed at the mouth of the single hydraulic fracture 950, and, hence, may reduce sand flow-back, for example.

In various illustrative embodiments, either the limited entry opening 510 (as shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in Figs. 7, 8, 11 and 12, for example) may be formed using at least one component disposed in a casing string. In various illustrative embodiments, either the limited entry opening 510 (as shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in Figs. 7, 8, 11 and 12, for example) may be provided after the well casing 530 (well casing and cement sheath 1130 in FIG. 11 and well casing and cement sheath 1230 in FIG. 12) is in place downhole.

In various illustrative embodiments, either the limited entry opening 510 (as shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in Figs. 7, 8, 11 and 12, for example) may be provided after the well casing 530 (well casing and cement sheath 1130 in FIG. 11 and well casing and cement sheath 1230 in FIG. 12) is in place downhole using slick-line methods, wireline methods, coiled tubing methods, jointed tubing methods, and/or jointed pipe methods inside the casing string. Additionally, the method may be used to recomplete the wellbore after previous wellbore openings have been sealed to allow for controlling treating fluid.

In various illustrative embodiments, either the limited entry opening 510 (as shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in Figs. 7, 8, 11 and 12, for example) may be provided after the well casing 530 (well casing and cement sheath 1130 in FIG. 11 and well casing and cement sheath 1230 in FIG. 12) is in place downhole using shape-change perforating methods, hydrojetting methods, hydrojetting methods, and/or methods comprising chemical dissolution of a material. In various illustrative embodiments, either the limited entry opening 510 (as
shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in FIGS. 7, 8, 11 and 12, for example) may be provided after the well casing 530 (well casing and cement sheath 1130 in FIG. 11 and well casing and cement sheath 1230 in FIG. 12) is in place downhole using hydrajetting perforating and/or hydrajetting slottting.

[0047] In various illustrative embodiments, as shown in FIG. 13, a method 1300 may be provided for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore. The method 1300 may comprise providing a single limited entry opening or a small cluster of limited entry openings in a well liner or casing and cement sheath allowing fluid communication between a region of a wellbore of not more than about 2 feet in length and a subterranean reservoir, as indicated at 1310. The method 1300 may also comprise controlling fluid entry using the limited entry opening or the cluster during an injection treatment of the subterranean reservoir, as indicated at 1310. The method 1300 may also comprise providing a proppant flow-back treatment following the injection treatment of the subterranean reservoir, as indicated at 1330. The method 1300 may also optionally comprise isolating the limited entry opening or the cluster from other areas of the subterranean reservoir, as indicated (in phantom) at 1340.

[0048] In various illustrative embodiments, as shown in FIG. 14, a method 1400 may be provided for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore. The method 1400 may comprise providing either a single limited entry opening or a small cluster of limited entry openings in a well liner or casing and cement sheath allowing fluid communication between a region of a wellbore of not more than about 2 feet in length and a subterranean reservoir, as indicated at 1410. The method 1400 may also comprise controlling fluid entry using the limited entry opening or the cluster during sequential injection treatments of the subterranean reservoir, as indicated at 1420. The method 1400 may also comprise providing a proppant flow-back treatment following each of the sequential injection treatments of the subterranean reservoir, as indicated at 1430. The method 1400 may also comprise isolating the limited entry opening or the cluster from other areas of the subterranean reservoir, wherein each cluster of limited entry openings in a vertical well implementation has the limited entry openings aligned substantially vertically, each cluster of limited entry openings in a deviated well implementation having an axis of a region of the wellbore deviated through an angle of about 0 below a horizontal direction has the limited entry openings aligned substantially at an angle of about

\[
\frac{\pi}{2} - \theta
\]

from the axis direction, and each cluster of limited entry openings in a horizontal well implementation has the limited entry openings aligned substantially radially, as indicated at 1440.

[0049] In various illustrative embodiments, as shown in FIG. 15, a method 1500 may be provided for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore. The method 1500 may comprise providing either a single limited entry opening or a small cluster of limited entry openings in a well liner or casing and cement sheath allowing fluid communication between a region of a wellbore of not more than about 2 feet in length and a subterranean reservoir, as indicated at 1510. The method 1500 may also comprise controlling fluid entry using the single fluid entry opening or small cluster of not more than about five limited entry openings during an injection treatment of the subterranean reservoir, as indicated at 1520. The method 1500 may also comprise providing a proppant flow-back treatment during or following the injection treatment of the subterranean reservoir, as indicated at 1530.

[0050] The method 1500 may also optionally comprise isolating the single fluid entry opening or small cluster of not more than about five limited entry openings from other areas of the subterranean reservoir, as indicated (in phantom) at 1540. The method 1500 may also optionally comprise providing the single fluid entry opening or small cluster of openings extending through a well casing, as indicated (in phantom) at 1550. The method 1500 may also optionally comprise providing the single fluid entry opening or small cluster of openings extending through a well casing and a cement sheath, and, optionally, into at least a portion of the subterranean reservoir, as indicated (parenthetically) at 1550. The method 1500 may also optionally comprise providing the single limited entry opening or small cluster of limited entry openings formed using at least one component disposed in a casing string, as indicated (in phantom) at 1560.

[0051] The method 1500 may also optionally comprise providing the single limited entry opening or small cluster of limited entry openings after the well casing is in place downhole, as indicated (in phantom) at 1570. The method 1500 may also optionally comprise providing the single limited entry opening or small cluster of limited entry openings after the well casing is in place downhole using, optionally, at least one of slick-line methods, wireline methods, coiled tubing methods, jointed tubing methods, and jointed pipe methods inside a casing string, as indicated (parenthetically) at 1570. The method 1500 may also optionally comprise providing the single limited entry opening or small cluster of limited entry openings after the well casing is in place downhole using, optionally, at least one of shape-charge perforating methods, hydrajetting methods, hydrajetting methods, and methods comprising chemical dissolution of a material, as indicated [in square brackets] at 1570. The method 1500 may also optionally comprise providing the single limited entry opening or small cluster of limited entry openings after the well casing is in place downhole using, optionally, at least one of shape-charge perforating methods, hydrajetting methods, hydrajetting methods, and methods comprising chemical dissolution of a material and using, optionally, at least one of hydrajetting perforating and hydrajetting slottting, as indicated [in square brackets { and in curly brackets }] at 1570.

[0052] In various illustrative embodiments, according to the present disclosure, a method and/or system for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore may use either a single limited entry opening or a small cluster of limited entry openings 710 of not more than about five limited entry
openings 710a (as shown in FIGS. 7, 8, 11 and 12, for example), at least one fluid entry opening 510, 710a comprising a relatively large hole (circular to elongated) and/or a slot (of substantially minimum adequate width W) through the well casing and cement sheath, as indicated at 530 (well casing and cement sheath 1130 in FIG. 11 and well casing and cement sheath 1230 in FIG. 12), possibly extending into the reservoir rock itself of the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12). As described above, many techniques may be used to create the specifically located hole(s) and/or slot(s), 510, 710a, even including methods that might include special components made up in the casing string, to completely independent techniques deployed after the casing is in place, using methods such as slick-line, wireline, coiled tubing, and/or jointed tubing and/or pipe inside the casing string. The techniques may even include a special application of shape-charge perforating technology, hydraulic jetting technology, chemical dissolution of a material and/or solid(s), and/or any other appropriate technique of current or future technology that may be applied to create the desired fluid entry opening 510 (as shown in FIG. 5, for example) or the cluster 710 of not more than about five limited entry openings 710a (as shown in FIGS. 7, 8, 11 and 12, for example) that are useful for the process of solids flow-back control. For example, hydrajetting perforating and/or hydraulic jetting slotting may be used to create a localized fluid entry location 520, 720, 820, 1120, 1220 for all injected fluid that may still have an adequate cross-sectional area that would not severely limit fluid production into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12).

In various illustrative embodiments, according to the present disclosure, a method and/or system for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) locations, each being isolated as the only point for fluid to exit the wellbore during the following treatment stages. This would allow the operator to need only the final portion of a specific injection treatment to contain needed flow-back control materials and/or chemical treatments, thereby reducing costs and improving over conventional methods. In various illustrative embodiments, according to the present disclosure, a method and/or system for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) may have application in substantially any fluid-producing reservoir, such as the subterranean reservoir 550 (subterranean reservoir 1150 in FIG. 11 and subterranean reservoir 1250 in FIG. 12), where either formation particles and/or injected solids need to be prevented from flowing back into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) along with the produced fluid.

In various illustrative embodiments, according to the present disclosure, a method and/or system for improving downhole flow-back control in oil and/or gas wells by controlling fluid entry into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12) may give substantially complete control of fluid entry point(s) during an injection treatment, such as a hydraulic fracturing treatment and/or a frac-pack treatment, and the like, so the operator may chose to only use a flow-back prevention method and/or chemicals in substantially the very final stages of solids injection, and/or to possibly squeeze in such a treatment after completion of the solids injection, but before beginning the flow-back stage. Moreover, the fluid entry location may have adequate cross-sectional area such that the fluid entry location may not be a major limitation to produced fluid flow into the wellbore 540 (wellbore 1140 in FIG. 11 and wellbore 1240 in FIG. 12). This gives positive control of injection location(s) without substantially restricting production, reducing costs over most conventional solids flow-back control methods, as well as allowing effective treatment of many other wells that need treatment, but that cannot support the costs of conventional technology and/or where conventional technology is not adequate.

To facilitate a better understanding of the present invention, the following examples of specific embodiments are given. No way should the following examples be read to limit or define the scope of the invention.

The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the present invention. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b"), disclosed herein is to be understood as referring to the power set (the set of all subsets) of the respective range of values, in the sense of Georg Cantor. Accordingly, the protection sought herein is as set forth in the claims below.

Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. While numerous changes may be made by those skilled in the art, such changes are encompassed within the spirit of this present invention as defined by the appended claims.

What is claimed is:

1. A method of controlling fluid downhole, comprising the steps of:

   providing either a single limited entry opening or a small cluster of limited entry openings in a well liner or casing and cement sheath allowing fluid communication between a region of a wellbore and a subterranean reservoir;

   controlling fluid entry using the single limited entry opening or small cluster of limited entry openings
during an injection treatment of the subterranean reservoir; and

providing a treatment.

2. The method of claim 1, wherein the treatment comprises a proppant flow back control treatment during or following a frac pack or hydraulic fracturing injection treatment of the subterranean reservoir.

3. The method of claim 1, wherein the treatment comprises a formation consolidation enhancement treatment.

4. The method of claim 1, wherein the step of providing a treatment is performed some time after a frac pack, hydraulic fracturing treatment, or gravel pack operation.

5. The method of claim 1, wherein the single limited entry opening or small cluster of limited entry openings cover no more than about 2 feet along the well bore.

6. The method of claim 1, wherein the method is used to recomplete the well bore after previous well bore openings have been sealed to allow for controlling treating fluid.

7. The method of claim 1, wherein the method is used to complete fewer than all sections of the well bore.

8. The method of claim 1, further comprising the step of using at least one of slick line methods, wireline methods, coiled tubing methods, jointed tubing methods, and jointed pipe methods inside a casing string to provide isolation of the zone with the single limited entry opening or small cluster of limited entry openings during injection treatment operations.

9. The method of claim 1, further comprising the step of using at least one of shape charge perforating methods, a hydrajecting method, or a method comprising chemical dissolution of a material to create the single limited entry opening or small cluster of limited entry openings.

10. The method of claim 9, wherein the step of providing the single limited entry opening or small cluster of limited entry openings is performed after the well casing is in place downhole using at least one of hydrajecting perforating and hydrajecting slotting.

11. The method of claim 1, wherein the total cross sectional area of the single limited entry opening or small cluster of limited entry openings is in a range of from about 0.5 square inches to about 10 square inches.

12. The method of claim 1, wherein the total cross sectional area of the single limited entry opening or small cluster of limited entry openings is in a range of from about 2 square inches to about 6 square inches.

13. The method of claim 1, wherein the step of providing the single limited entry opening or small cluster of limited entry openings further comprises providing a slot having a width in a range of from about ½ inch to about 1 inch.

14. The method of claim 1, wherein the step of providing the single limited entry opening or small cluster of limited entry openings further comprises providing a slot having a width in a range of from about ½ inch to about ½ inch.

15. A method of controlling fluid downhole, comprising the steps of:

providing either a single limited entry opening or a small cluster of limited entry openings in a well liner or casing and cement sheath allowing fluid communication between a region of a well bore and a subterranean reservoir;

controlling fluid entry using the single limited entry opening or small cluster of limited entry openings during an injection treatment of the subterranean reservoir;

providing a proppant flow back treatment following the injection treatment of the subterranean reservoir; and

isolating the single limited entry opening or small cluster of limited entry openings from other areas of the subterranean reservoir.

16. The method of claim 15, wherein the well casing and cement sheath extends into at least a portion of the subterranean reservoir, allowing fluid communication between the region of the well bore of about 2 feet in length and the subterranean reservoir.

17. The method of claim 15, wherein the single limited entry opening or small cluster of limited entry openings is formed using at least one component disposed in a casing string.

18. The method of claim 15, further comprising placing a well casing downhole prior to providing the single limited entry opening or small cluster of limited entry openings.

19. The method of claim 18, wherein placing the well casing downhole comprises using at least one of slick line methods, wireline methods, coiled tubing methods, jointed tubing methods, and jointed pipe methods inside a casing string.

20. The method of claim 15, wherein providing either a single limited entry opening or a small cluster of limited entry openings comprises using at least one of shape charge perforating methods, hydrajetting methods, and methods comprising chemical dissolution of a material.

21. The method of claim 20, further comprising using at least one of hydrajetting perforating and hydrajetting slotting.

22. The method of claim 15, wherein the single limited entry opening or small cluster of limited entry openings has a cross sectional area in a range of from about 1 square inch to about 10 square inches.

23. The method of claim 15, wherein the single limited entry opening or small cluster of limited entry openings has a cross sectional area in a range of from about 2 square inches to about 6 square inches.

24. The method of claim 15, wherein the single limited entry opening or small cluster of limited entry openings has a width in a range of from about ½ inch to about 1 inch.

25. The method of claim 15, wherein the single limited entry opening or small cluster of limited entry openings has a slot having a width in a range of from about ½ inch to about ½ inch.

26. A method of controlling fluid downhole, comprising the steps of:

providing either a single limited entry opening or a small cluster of limited entry openings in a well liner or casing and cement sheath allowing fluid communication between a region of a well bore and a subterranean reservoir;

controlling fluid entry using the single limited entry opening or small cluster of limited entry openings during sequential injection treatments of the subterranean reservoir;
providing a proppant flow back treatment following each of the sequential injection treatments of the subterranean reservoir; and

isolating the single limited entry opening or small cluster of limited entry openings from other areas of the subterranean reservoir, wherein each limited entry opening in a vertical well implementation has the limited entry opening aligned substantially vertically, each limited entry opening in a deviated well implementation having an axis of a region of the well bore deviated through an angle of about below a horizontal direction has the limited entry opening aligned substantially at an angle of about from the axis direction, and each cluster of limited entry opening in a horizontal well implementation has the limited entry opening aligned substantially radially.

27. The method of claim 26, wherein the single limited entry opening or small cluster of limited entry openings has a cross sectional area in a range of from about 1 square inch to about 10 square inches and a slot having a width in a range of from about $\frac{1}{8}$ inch to about 1 inch.

28. The method of claim 26, wherein the single limited entry opening or small cluster of limited entry openings is formed using at least one component disposed in a casing string.

29. The method of claim 26, further comprising the step of placing a well casing downhole before the step of providing the single limited entry opening or small cluster of limited entry openings.

30. The method of claim 29, wherein the step of placing the well casing downhole comprises using at least one of slick line methods, wireline methods, coiled tubing methods, jointed tubing methods, and jointed pipe methods inside a casing string.

31. The method of claim 26, wherein providing either a single limited entry opening or a small cluster of limited entry openings comprises using at least one of shape charge perforating methods, hydrajetting methods, hydrojetting methods, and methods comprising chemical dissolution of a material.

32. The method of claim 31, further comprising using at least one of hydrajetting perforating and hydrajetting slotting.

33. The method of claim 26, wherein the single limited entry opening or small cluster of limited entry has a cross sectional area in a range of from about 2 square inches to about 6 square inches.

34. The method of claim 26, wherein the single limited entry opening or small cluster of limited entry openings has a slot having a width in a range of from about $\frac{1}{8}$ inch to about $\frac{1}{2}$ inch.

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