SYSTEM FOR CONTROLLING CEMENT FLOW IN A WELL

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ABSTRACT

A method for preventing undesired cement flow in a well containing a tubing string, comprises: determining a desired pressure drop for a desired flow rate at a desired location in the tubing string, determining a flow area that will cause the desired pressure drop, and installing in the tubing string a choke having at least one port, wherein the total area of the ports equals the desired flow area. The choke may include at least two ports, one of which may include a least one rupture disk disposed selected to rupture when the pressure drop across the choke exceeds a predetermined value. The choke may be below a float collar in the well. The invention allows the use of foamed cement and in particular foamed cement having a density that is less than the lowest density that could have been used if the choke were not in place.
SYSTEM FOR CONTROLLING CEMENT FLOW IN A WELL

RELATED CASES

This application claims priority from U.S. application Ser. No. 61/413,676, filed 15 Nov. 2010, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

The invention relates to a system and method for preventing undesired cement flow in a well containing a tubing string, including installing in the tubing string a choke having at least one port with a desired flow area.

BACKGROUND OF THE INVENTION

Subsequent to drilling a borehole of an oil or gas well, casing or liner is run into the well and a cement slurry is placed in the annulus between the outside of the casing and the borehole wall.

Referring initially to FIG. 1, a typical arrangement will include a borehole 10 into which a casing or liner string 12 extends, forming an annulus 11 between the borehole wall and the outside of casing 12. In some instances string 12 will hang from a second tubing string 16 that is placed higher in the well. In such instances, a hanger 18 supports string 12. String 12 is typically provided with a float collar 14 near its lower end. When it is desired to cement string 12 in the well, a landing string 17 is positioned such that its lower end is within the upper end of string 12. A packer 15 seals the annulus 19 between string 17 and string 12. As illustrated in FIG. 1, at least four pressure zones are created in such a system, namely a first zone 30 within string 17, second zone 32 within string 12 and above collar 14, a third zone 34 within string 12 and below collar 14, and a fourth zone 36 between string 12 and the wellbore.

When it is desired to perform a cementing operation, a calculation is made to determine the volume of cement that will be required in order to fully occupy the desired space. Once the pre-determined amount of cement has been pumped into the well, a second fluid, often drilling fluid or water, is pumped behind the cement to displace the cement out the bottom of the casing and up into the annulus between the casing and borehole wall. The cement slurry is usually raised to a point above the uppermost section of the formations to be isolated and may be raised into the annulus between the casing string being cemented and a previously cemented casing.

A positive pressure difference between zone 34 and zone 36 is required in order to place the cement in the annulus. When the cement is not flowing, the pressure in zone 34 is the hydrostatic pressure of the cement column above zone 34. When the cement is flowing, i.e. being pumped into the well, the pressure in zone 34 is the hydrostatic pressure of the cement column above zone 34 less the pressure drop attributable to friction and any pressure drop across collir 14.

It has been found that in some instances, the pressure in zone 34 is so much greater than the pressure in zone 36 that the cement flows from zone 34 to zone 36 more rapidly than desired. This may occur, for instance, when the cement is significantly denser than the fluid in annulus 11. This pressure differential then causes fluid to move uncontrollably faster, resulting in excessive annular frictional pressure drop and uncertainty in fluid location within the wellbore.

In addition, a differential pressure typically exists between the fluid column in the annulus (zone 36) and the pore pressure of the exposed formation. The hydrostatic pressure in zone 36 immediately after the cement is placed is typically designed to be higher than the pore pressure of exposed formations in order to prevent flow of formation fluids into the annulus. It is also desirable, however, to ensure that the pressure in zone 36 is less than the fracturing pressure of the exposed formation, since otherwise the formation would fracture and the cement slurry would flow into the formation rather than filling up the annulus around the casing.

To reduce the likelihood of losses into the formation, lightweight cements have been developed. Low-density cement slurries can be provided by including in the slurry a low-density aggregate such as graphite or hollow spheres, by diluting the cement with additional water, or by creating a foam from the slurry. By way of example only, typical oil-gas-well slurries can have densities of 1380 kg/m³ to 2280 kg/m³ (11.5 lbm/gal to 19.0 lbm/gal) while fluids used in specialized techniques, such as foamed cementing and particle-size distribution cementing, can extend this range to 840 kg/m³ to 2760 kg/m³ (7 lbm/gal to 23 lbm/gal).

When foamed cement is being used, the rate of flow from zone 34 to zone 36 may be such that an undesirable pressure drop occurs in zone 32 or zone 30. Such a pressure drop can cause gas bubbles in the cement to coalesce into larger and less stable bubbles. Extremely large bubbles, or pockets of gas in the cement are undesirable for many reasons, including their effect on cement integrity. Gas pockets can also increase the certainty of cement placement within a well.

Additionally, this rate of flow resulting the aforementioned excessive pressure in zone 36 may be uncontrollable, not only resulting in excessive pressure in zone 36 but also very low pressure in zone 30. Commonly referred to as a U-tubing effect, the outcome can be uncontrollable placement of the cement slurry and subsequent formation failure in zone 36 or unacceptably low pressure in zone 30. The purpose of this invention is to provide a means to induce a back-pressure inside the casing, thus limiting or eliminating the U-tube effect.

By controlling the cement flow rate and thus the pressure in zones 30 and 32, the flow of cement into the annulus can be controlled, resulting in turn in better control over the placement and quality of the cement, especially that of foamed cements. There remains a need for a system or apparatus that would provide such control.

SUMMARY OF THE INVENTION

In accordance with preferred embodiments of the invention there is provided for controlling the cement pressure. Thus the present invention also provides means for controlling the flow of cement into the annulus, resulting in turn in better control over the placement and quality of the cement.

As used in this specification and claims the following terms shall have the following meanings:

"Above," "upper," and "uphole," shall all refer to objects or locations that are relatively closer to the surface than a second object or location.

In certain embodiments, the present invention provides a method for preventing undesired cement flow in a well containing a tubing string, comprising the steps of: a) determining a desired pressure drop for a desired flow rate at a
desired location in the tubing string; b) determining a flow area that will cause the desired pressure drop; and c) installing in the tubing string a choke having at least one port, wherein the total cross-sectional area of the port or ports equals the desired flow area.

[0017] The choke may include at least two ports and may further include at least one rupture disk disposed in a port and at least one port that is unobstructed. The rupture disk is selected to rupture when the pressure drop across the choke exceeds a predetermined value.

[0018] The choke may be positioned in the well below a float collar or the like. The method may further include the step of cementing the well using foamed cement and, if desired, the foamed cement may have a density that is less than the lowest density that could have been used if the choke were not in place.

[0019] The desired pressure drop across the choke may be in the range of between 100 (0.69 MPa) and 1000 psi (6.9 MPa) and in some embodiments at least one port can be actuated from a closed mode to an open mode.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0020] For a more detailed understanding of the invention, reference is made to the accompanying wherein:

[0021] FIG. 1 is a schematic illustration of a conventional cementing arrangement; and

[0022] FIG. 2 is a schematic illustration of a cementing arrangement configured in accordance with one embodiment of the present invention.

**DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT**

[0023] Referring now to FIG. 2, the strings 12, 16 and 17, packer 15, and float collar 14 are configured essentially as set out above with respect to FIG. 1. In addition to float collar 14 near the bottom of string 12, a choke 20 is included in string 12. Choke 20 creates an additional pressure zone, 33, which is below float collar 14 and above choke 20. Choke 20 comprises a body 20 that is affixed to the inner surface of string 12 and includes at least one and preferably a plurality of longitudinal bores or ports 24 extending therethrough. As discussed below, the total area of bore(s) 24 is preferably determined based on the desired pressure drop across choke 20 and the anticipated viscosity, density, pressure, and flow rate of the cement.

[0024] As is known in the art, a constriction in the flow of an inviscid, incompressible fluid will cause a pressure drop $\Delta P$ that is a function of the fluid density and the velocities of the fluid upstream of the constriction and at the constriction, per Eq. (1):

$$\Delta P = \frac{\rho}{2} \left( v_1^2 - v_2^2 \right)$$

[0025] Since the velocity is dependent on flow area for an incompressible fluid,

$$v_2 = v_1 \left( \frac{A_1}{A_2} \right)$$

and $\Delta P$ can be expressed as function of the ratio of flow areas:

$$\Delta P = \frac{\rho}{2} v_1^2 \left( \frac{A_1}{A_2} \right)^2 - 1)$$

where $\rho$ = density, $v_1$ and $v_2$ are the velocity upstream and at the choke, respectively, and $A_1$ is the cross-sectional area of zone 33 and $A_2$ is the sum of the cross-sectional areas of bore(s) 24, respectively. To compensate for frictional losses and the effect of viscosity, a discharge coefficient may be included in the equation.

[0026] In preferred embodiments, choke 20 comprises a drillable plate that is inserted in the casing/liner string to be cemented in place below any float collar or landing collar, so as to avoid interference with any existing casing/liner hardware. The diameter(s) and total area of bore(s) 24 is selected so that a specific, desired back-pressure will be induced inside the casing at the intended flow rate(s).

[0027] By way of example only, in a 9½ inch (24.5 cm) liner, the ID of the liner will be 8.535 inches (21.7 cm) and choke 20 may include 4 bores each having a diameter of ½ inches (6.4 cm). At total flow rates in the range of 3 bbl/min to 4 bbl/min this configuration would result in a pressure drop of 320 psi (2.2 MPa) to 570 psi (3.9 MPa) across choke 20.

[0028] In preferred embodiments, one or more of bores 24 may include a rupture disk 26 therein. Rupture disks may be conventional rupture disks such as are known in the art. The purpose of the rupture disks is to allow continued fluid flow in the event bores 24 become plugged or the induced back-pressure in zone 33 is higher than intended. Each rupture disk can be optionally designed to fail at various pressures. By way of example only, one rupture disk may be designed to fail when the pressure in zone 33 is 250 psi (1.7 MPa) above desired backpressure, a second rupture disk may be designed to fail when the pressure in zone 33 is 500 psi above desired backpressure. In some embodiments, it may be desirable to provide rupture disks having a total area equal to or greater than the total flow area of bores 24.

[0029] By way of further example, Table 1 is provided below.

<table>
<thead>
<tr>
<th>Flow rate (bbl/min)</th>
<th>Flow Port diameter</th>
<th>RD1 750 psi</th>
<th>RD2 1,000 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>½&quot;</td>
<td>½&quot;</td>
<td>1&quot;</td>
</tr>
<tr>
<td>6</td>
<td>¾&quot;</td>
<td>¾&quot;</td>
<td>1⅛&quot;</td>
</tr>
<tr>
<td>8</td>
<td>¾&quot;</td>
<td>¾&quot;</td>
<td>1⅛&quot;</td>
</tr>
</tbody>
</table>

[0030] In preferred embodiments, choke 20 comprises a concrete or composite body with brass/aluminum sleeves in bores 24 for wear/erosion protection. It will be recognized by those skilled in the art that choke 20 may be constructed in any manner and of any materials that are suitable for use in a downhole environment.

[0031] By inducing controlled back-pressure inside the casing, i.e. in zone 30, 32, and 33, choke 20 reduces the U-tube effect and allows more control and placement of the cementing fluids. It also reduces the risk of bubble coalescence during foamed cementing operations.

[0032] In addition, positive pressure indications during the cementing operation helps ensure proper placement and displacement of fluids and ensures better control over the entire
pumping process, thus a better-quality cementation of the pipe in the wellbore. In turn, the present invention allows the use of foamed cements having a higher gas/liquid ratio than would otherwise be possible, enabling lower effective density cement slurries to be pumped with control.

[0033] The present invention avoids interference with subsea plug launch systems, as well as ensuring that the back-pressure is present during the entire mixing and displacement. Further, the present invention allows for normal cementing operations with minimum modifications to the current casing design.

[0034] While the present invention has been described herein in terms of preferred embodiments, it will be understood that various modifications can be made thereto without departing from the scope of the invention, which is established by the claims that follow. For example, the dimensions, configuration, orientation, materials, and number of the present choke that are used in a given well can vary and are limited only by their suitability for that well. By way of specific examples: bore(s) 24 do not need to be longitudinal or cylindrical, so long as they extend from zone 33 to zone 34; rupture disks 26 need not be disposed in the radially outer bore(s); and the distance between choke 20 and float collar 14 can be set to any desired value or order in the pipe string. It is also envisioned that controllable embodiments of choke 20 can be constructed, in which one or more bore(s) 24 can be actuated to an open mode as desired, using a control mechanism or signal from the surface or elsewhere.

What is claimed is:

1. A method for preventing undesired cement flow in a well containing a tubing string, comprising the steps of:
   a) determining a desired pressure drop for a desired flow rate at a desired location in the tubing string;
   b) determining a flow area that will cause the desired pressure drop; and
   c) installing in the tubing string a choke having at least one port, wherein the total cross-sectional area of the port or ports equals the desired flow area.

2. The method according to claim 1 wherein the choke includes at least two ports.

3. The method according to claim 1 wherein the choke includes at least one rupture disk disposed in a port and at least one port that is unobstructed.

4. The method according to claim 3 wherein the rupture disk is selected to rupture when the pressure drop across the choke exceeds a predetermined value.

5. The method according to claim 1 wherein step c) comprises installing the choke below a float collar in the well.

6. The method according to claim 1, further including the step of:
   d) cementing the well using foamed cement.

7. The method according to claim 6 wherein the foamed cement has a density that is less than the lowest density that could have been used if the choke were not in place.

8. The method according to claim 1 wherein the desired pressure drop is in the range of between 100 (0.69 MPa) and 1000 psi (6.9 MPa).

9. The method according to claim 1 wherein at least one port can be actuated from a closed mode to an open mode.