Abstract: A method for bonding a well bore to a casing may include several steps. Casing may be introduced into the well bore and pulses of fluid may be directed from within the casing into the well bore. An annulus between an inner surface of the well bore and an outer surface of the casing may be filled with fluid. A method for reducing fluid or gas migration into a fluid in the annulus may include inducing pressure pulses in the fluid before the fluid has cured.
METHODS FOR INTRODUCING PULSING TO CEMENTING OPERATIONS

BACKGROUND

[0001] The present invention relates to cementing operations, and, more particularly, methods and apparatuses for providing more competent cement bonds during and after cementing operations in well bores.

[0002] Settable compositions such as cement slurries may be used in primary cementing operations in which pipe strings, such as casing and liners, are cemented in well bores. In performing primary cementing, a cement may be pumped through the casing into an annulus between the walls of a well bore and the casing disposed therein. The cement typically is pumped into this annulus until it reaches a predetermined height in the well bore to provide zonal isolation. The cement cures in the annulus, thereby forming an annular sheath of hardened cement (e.g., a cement sheath) that supports and positions the pipe string in the well bore and bonds the exterior surface of the pipe string to the walls of the well bore.

[0003] Fluid or gas influx into the annulus and cement therein during the cement curing or “gelling” stage is quite common. This fluid or gas influx can damage the cement bond between the well bore formation and the exterior surface of the casing. Moreover, the buildup of residues such as filter cake on or in the surface of the well bore also can prevent a complete bond between the cement and the well bore. Figure 1 illustrates an example of such damage and incomplete bonding in a small section of formation 100 containing well bore 101 with casing 102. Cement 103 fills annulus 104 between the walls of well bore 101 and the exterior surface of casing 102. Pockets 105 and 106 illustrate examples of damage caused by fluid or gas influx. If the fluid or gas invasion is severe, channels will form between formation 100 and the exterior surface of casing 102, such as channels 107 and 108. Influx damage can occur at the interface between cement 103 and well bore 100, or in the cement 103 itself. Filter cake 109 also can prevent complete bonding between well bore 101 and cement 103. Conventional methods of filter cake removal often rely on mechanical means such as scratchers with pipe reciprocation or require that cement 103 reach a specific annular velocity. These removal methods can be time-consuming and often leave filter cake residues behind, impeding bonding between cement 103 and well bore 101.
SUMMARY

[0004] The present invention relates to cementing operations, and, more particularly, methods and apparatuses for providing more competent cement bonds during and after cementing operations in well bores.

[0005] A method for bonding a well bore to a casing therein, may comprise the steps of introducing the casing into the well bore, directing pulses of fluid from within the casing into the well bore, and filling an annulus between an inner surface of the well bore and an outer surface of the casing with the fluid. The step of directing pulses of fluid may performed while moving the casing further into the well bore. Additionally or alternatively, the method may further comprise the step of selecting a frequency and pressure level for the pulses of fluid so as to reduce filter cake formed on the inner surface of the well bore. Additionally or alternatively, the method may further comprise the step of vibrating well fluid at a resonance frequency for the well fluid. Additionally or alternatively, the method may further comprise the step of vibrating the casing at a resonance frequency for the casing. Vibrating the casing at a resonance frequency may comprise the step of directing pulses of fluid into the well bore at a frequency and pressure selected to induce resonance vibrations in the casing. Additionally, or alternatively, the fluid may be a cement. If the fluid is a cement, the method may further comprise the step of selecting a frequency and pressure level for the pulses of fluid so as to reduce the amount non-cement material on the casing, and the method may further comprise the step of selecting a frequency and pressure level for the pulses of fluid so as to reduce filter cake formed on the inner surface of the well bore, such that the pulses have a dual-step profile.

[0006] A method for reducing fluid or gas migration into a fluid in an annulus formed between a surface of a well bore in a formation and a casing, may comprising the step of inducing pressure pulses in the fluid before the fluid has cured. The fluid may be a cement. The method may further comprise the step of selecting a frequency and amplitude for the pressure pulses such that the pressure pulses prevent shear damage of the fluid during curing. The step of inducing pressure pulses in fluid before the fluid has cured may comprise the step of inducing a low-amplitude pressure pulse. Additionally, or alternatively, the step of inducing pressure pulses in fluid before the fluid has cured may comprise the step of inducing a low-frequency pressure pulse. Alternatively, the step of inducing pressure pulses in fluid
before the cement has cured may comprise the step of inducing a pressure pulse having a
dual-step profile.

[0007] The features and advantages of the present invention will be readily
apparent to those skilled in the art. While numerous changes may be made by those skilled in
the art, such changes are within the spirit of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] These drawings illustrate certain aspects of some of the embodiments
of the present invention, and should not be used to limit or define the invention.

[0009] Figure 1 illustrates conventional cement bonding.

[0010] Figure 2 illustrates a method for bonding a well bore to a casing in
accordance with one embodiment of the present invention.

[0011] Figure 3 illustrates an alternate embodiment of a method for bonding a
well bore to a casing.

[0012] Figure 4 illustrates yet another embodiment of a method for bonding a
well bore to a casing.

[0013] Figure 5 illustrates various pressure pulses in accordance with one
embodiment of the present invention.

[0014] Figure 6 illustrates a shear damage profile in accordance with one
embodiment of the present invention.

[0015] Figure 7 illustrates a fluidic oscillator in accordance with one
embodiment of the present invention.

[0016] Figure 8 illustrates an alternate embodiment of a method for bonding a
well bore to a casing.

[0017] Figure 9 illustrates yet another embodiment of a method for bonding a
well bore to a casing.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0018] The present invention relates to cementing operations, and, more
particularly, methods and apparatuses for providing more competent cement bonds during
and after cementing operations in well bores.

[0019] These methods and apparatuses may result in less fluid influx during
the pre and post gelling stage of a cement slurry or other fluid, resulting in significant savings
in time and cost, and improved hydrocarbon recovery.
[0020] Typically, a cementing operation involves attaching float shoe 110 to an end of casing 102 and introducing casing 102 into well bore 101. Cement 103 may then flow down the interior of casing 102 and out through float shoe 110 into annulus 104. Alternatively, a reverse cementing operation may be used to place cement 103 in annulus 104. In either instance, as cement 103 enters annulus 104, it displaces material such as drilling fluid, filter cake, gas, or debris occupying annulus 104. Typically, as cement 103 enters annulus 104, some material occupying annulus 104 remains, particularly near the walls of well bore 101 and casing 102. In other words, a displacement efficiency of the material is typically significantly below 100% efficiency, which would correspond to the instance when cement 103 completely displaces the material occupying annulus 104. Low displacement efficiency results in undesirable channeling and pocketing, which causes the cement bond to be compromised.

[0021] The material may be more completely replaced by cement 103 when pulsing or oscillation is used during the introduction of cement 103 into annulus 104. A number of devices rely on fluid oscillation effects to create pulsating fluid flow. Generally, these devices connect to a source of fluid flow, provide a mechanism for oscillating the fluid flow between two different locations within the device and emit fluid pulses downstream of the source of fluid flow. These "fluidic oscillator" 112 devices require no moving parts to generate the oscillations and have been used in various applications for which pulsating fluid flow is desired, such as massaging showerheads, flow meters, and windshield-wiper-fluid-supply units. Specialized fluidic oscillator devices have been developed for the oilfield industry, such as, for example, the Pulsonix TF tool offered by Halliburton Energy Services, Inc. of Duncan, Oklahoma.

[0022] In addition to providing for more complete displacement of materials in annulus 104, fluidic oscillator 112 may help mitigate fluid and/or gas migration during cement cure time. As shown in Figure 2, fluidic oscillator 112 may be present in float shoe 110. In this embodiment, a feedback loop may be scaled and adapted to allow desired flow rates and cement passages to allow application into a Super Seal II float shoe by matching flow areas of the 2-3/4" or 4-1/4" Super Seal II Valves. This may allow for filter cake 109 removal while running in hole using a top drive unit. Filter cake 109 may be removed more effectively by direct fluid impingement of the well bore 101. Once total depth ("TD") is reached reduced well conditioning time (bottoms up) may be required, since filter cake may
be removed hydraulically while running in hole, instead of requiring cleaning at a specific annular velocity or by mechanical means such as scratchers and pipe reciprocation. Pulsing may break down gel strength, fragmenting or breaking down filter cake 109.

[0023] Referring now to Figure 3, an additional benefit of fluidic oscillator 112 in float shoe 110 may be available in either standard or top drive applications. As a result of the oscillatory effect at float shoe 110, cement 103 is displaced more effectively at the walls of well bore 101 and casing 102. The oscillation effect tends to place cement 103 further into formation 100, compacting cement 103, which results in fewer voids due to filter cake contamination entrapment or consistency issues. Another potential advantage is that casing 102 may be set into resonance by the oscillation at float shoe 110. This resonance tends to prevent voids at the wall of casing 102. The resonance and compaction effect continuously occurs from the beginning of the displacement until the top plug lands or pumping is discontinued. Alternatively, or additionally, frequency may be set such that the well bore fluids are set into resonance.

[0024] Since each well will have different frequency variables, such as fluid, rate, and geometry, it may be particularly useful for fluidic oscillator 112 to have variable components. A fluctuating or variable fluidic oscillator 112 may be used to allow for alternating resonance of casing 102 and well bore fluids. A high frequency component, a low frequency component, or a combination of the two may enhance the effectiveness of the system. These components may be further combined with either high or low amplitude components, or both. To reach the various resonance ranges, variable rate or "dual-step profile" pumping may be used. Alternatively, two or more fluidic oscillators 112 could be used to alternate between two or more resonances.

[0025] As an alternative to alternating between multiple frequencies and/or amplitudes, a specific design may be used for a specific well bore fluid system. As more cement 103 is pumped, resonant frequency will change. Thus it may be desirable for fluidic oscillator 112 to change based on changes in the system. This may be a result of monitoring of instrumentation measuring the level of excitation. This may be done with a sensor such as a hydrophone, a pressure transducer, a flow device, an accelerometer, or any number of other devices known in the art. This monitoring may allow for fluidic oscillator 112 to maintain resonance.
Referring now to Figure 4, in an alternative embodiment, low frequency, low pressure pulses are induced after the plug has landed and the curing has begun. A pressure pulsation tool 114 may be optimized from its normal high amplitude/low frequency configuration to a low amplitude/low frequency tool by way of configurable inserts and pump rate control. Pressure pulsation tool 114 may be encapsulated in a canister and used in conjunction with a reservoir system to create a surface cement pulsation system to apply low pressure/low frequency pressure pulses to annulus 104 to delay the curing time and prevent fluid migration as a result of cement volume reduction.

Idealized pressure wave forms can be controlled to provide optimal pulsation and help prevent shear of cement 103 during dehydration. Examples of what the inventors envision as optimal pressure pulses are illustrated in Figure 5. These profiles may prevent shear damage to cement 103, as indicated in Figure 6.

Yet another embodiment involves a low cost "tubing" size fluidic oscillator 112, as shown in Figure 7. This fluidic oscillator 112 may be composed of phenolic inserts cemented into a low cost case. Cement 103 may be fairly resistant to acid, thus allowing application to hydraulic work order ("HWO") or Well Intervention applications in addition to cementing applications.

The concept of "pulsing" the top plug after catching cement is illustrated in Figure 8. A pulse generator capable of pumping cement may allow for pulsing on the fly or, as illustrated, pulsing of the displacement fluid could be accomplished.

Pulsation or oscillation may be used to set more competent balanced plugs. Shown in Figure 9 is an oscillation guide shoe 113 used with either the tubing release tool ("TRT") or bottom hole kickoff assembly ("BHKA") tool. Retrieving drillpipe adapter and collet retainer 115 may be removed as releasing plug 116 is latched and collet is disengaged, releasing tubing. Alternatively, pressure pulsation may be used during hesitant squeeze cementing (not shown).

This disclosure covers two basic fluid energy principles: fluidic oscillation and pressure pulsing technology. These two principles can be used during or after the cementing job. This technology is adaptable for both primary cementing and setting of balanced plugs.

This technology potentially could reduce sustained casing pressure which is a major concern particularly offshore. Earlier methods do not consider the advantage of inducing...
fluid energies by fluidic oscillation or pressure pulsation methods. This methodology greatly enhances the chances for competent cement bonding.

[0032] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. 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," or, equivalently, "from approximately a-b") disclosed herein is to be understood as referring to the power set (the set of all subsets) of the respective range of values, and set forth every range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.
What is claimed is:

1. A method for bonding a well bore to a casing therein, comprising the steps of:
   introducing the casing into the well bore;
   directing pulses of fluid from within the casing into the well bore; and
   filling an annulus between an inner surface of the well bore and an outer surface of the casing with the fluid.

2. The method of claim 1, wherein the fluid is a cement.

3. The method of claim 1, wherein the step of directing pulses of fluid is performed while moving the casing further into the well bore.

4. The method of claim 1, further comprising the step of selecting a frequency and pressure level for the pulses of fluid so as to reduce filter cake formed on the inner surface of the well bore.

5. The method of claim 2, further comprising the step of selecting a frequency and pressure level for the pulses of fluid so as to reduce the amount non-cement material on the casing.

6. The method of claim 5, further comprising the step of selecting a frequency and pressure level for the pulses of fluid so as to reduce filter cake formed on the inner surface of the well bore, such that the pulses have a dual-step profile.

7. The method of claim 1, further comprising the step of vibrating the casing at a resonance frequency for the casing.

8. The method of claim 7, wherein the step of vibrating the casing at a resonance frequency comprises the step of directing pulses of fluid into the well bore at a frequency and pressure selected to induce resonance vibrations in the casing.

9. The method of claim 1, further comprising the step of vibrating well fluid at a resonance frequency for the well fluid.

10. A method for reducing fluid or gas migration into a fluid in an annulus formed between a surface of a well bore in a formation and a casing, comprising the step of inducing pressure pulses in the fluid before the fluid has cured.

11. The method of claim 10, wherein the fluid is a cement.
12. The method of claim 10, further comprising the step of selecting a frequency and amplitude for the pressure pulses such that the pressure pulses prevent shear damage of the fluid during curing.

13. The method of claim 10, wherein the step of inducing pressure pulses in fluid before the fluid has cured comprises the step of inducing a low-amplitude pressure pulse.

14. The method of claim 10, wherein the step of inducing pressure pulses in fluid before the fluid has cured comprises the step of inducing a low-frequency pressure pulse.

15. The method of claim 10, wherein the step of inducing pressure pulses in fluid before the cement has cured comprises the step of inducing a pressure pulse having a dual-step profile.