Systems and methods for vibrating coiled tubing as it is moved in an earth wellbore.
COILED TUBING VIBRATION SYSTEMS AND METHODS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to coiled-tubing systems and methods.

2. Description of Related Art

Coiled tubing ("CT") systems are used to perform drilling or intervention operations ("coiled tubing operations" or "CTO") in wells. FIG. 1 illustrates a prior art CT system 100, used for CTO. The CT 102 is stored on the reel 101. The CT 102 is run into the well 106 below the surface 108 by bending around a guide arch 103, passing through an injector 104 and a well control stack 105. A bottom-hole assembly (BHA) 107 is often attached to the end of the CT. The surface 108 may be ground level or a rig floor when on land. Offshore it may be the surface of the water or the floor of a rig or platform, or the sea floor.

FIG. 2 illustrates a similar prior art CTO system 200. The CT 102 is pulled off of the storage reel 101 by a small injector 209. It then loops upwards through the air in what is known as a CT arch 210 and enters the top of the injector 104 without bending around the guide arch 103. U.S. Pat. No. 6,142,406 discusses a control system for maintaining such an arch. The large radius of curvature of the CT arch 210 significantly decreases the bending fatigue life of the CT 102, when compared to the much smaller bending radius of the guide arch 103 used in 100. In other systems the arch 210 is deleted.

There are several types of CT injectors 104. Typical contra-rotating chain injectors are shown, e.g., in U.S. Pat. Nos. 5,309,990 6,059,029 and 6,216,780. A driven roller style CT injector 104 and a CT arch are shown in U.S. Pat. No. 6,530,432.

Often in CTO there is difficulty in accurately transmitting force to the BHA 107 through the CT 102, while moving the CT in the well. Moving the CT in the well occurs when running in the hole ("RIH") or pulling out of the hole ("POOH") or, in the case of a drilling operation, while drilling ahead. This difficulty is due to friction between the well 106 and the CT 102. This friction is caused by; the weight of the CT 102 and the BHA 107, belt or capstan friction due to curvature of the well 106, buckling of the CT 102 inside the well 106, bending of the CT 102 and BHA 107 when passing around curves in the well 106, surface roughness and lubricity of the well 106 CT 102 and BHA 107.

Several things are done during CTO in various prior art systems and methods to reduce this friction. Vibration (which reduces or eliminates friction) devices (e.g., device 111 shown schematically) have been developed that are run as part of the BHA 107. These devices attempt to vibrate the bottom end of the CT 102 to mitigate the friction. Other devices, such as tractors or pullers, are sometimes added to the BHA 107 to provide the axial force at the BHA instead of relying upon axial force provide through the CT 102. Sometimes slick fluids are circulated through the CT 102 to improve the lubricity between the well 106 and the CT 102 and BHA 107. All of these things work to some extent, but friction between the CT 102 and the well 106 is still a major impediment to some CTO.

U.S. Pat. No. 6,412,856 discusses an oscillating apparatus when can be added above a CT injector. This apparatus gives a detailed history of various systems which attempt to use vibration to free stuck pipe. The purpose of this oscillating apparatus is to free stuck pipe by oscillating or vibrating the CT. This system works by gripping the CT with the oscillator, then releasing it with the CT injector. The oscillator then vibrates the CT in the axial direction, varying the vibration frequency in an attempt to reach a resonant frequency, and hopefully free the stuck CT and/or BHA. This oscillator cannot be operated while RIH or POOH, or while drilling ahead.

There is a need, recognized by the present inventors, for a system which vibrates CT at the surface to reduce the friction between the CT and the well while moving the CT in the well.

SUMMARY OF THE PRESENT INVENTION

The present invention, in at least certain embodiments, teaches a system to vibrate coiled tubing from the surface to mitigate friction in a well. These vibrations may cause axial, lateral, and/or rotational movement of the CT. The amplitude and/or frequency of the vibration will vary during the CTO depending on the amount and depth of friction mitigation desired. A large amplitude of movement (either axial, rotational, or both) may be called reciprocation or oscillation. For purposes of this patent "vibration" refers to all types of periodic motion of the CT created intentionally to mitigate friction. In one aspect, the present invention discloses methods for employing coiled tubing in a wellbore, the methods including moving coiled tubing into a wellbore in the earth, the wellbore extending from the earth surface down into the earth, and vibrating the coiled tubing as it is moved in the wellbore to reduce friction between the coiled tubing and the wellbore. In one aspect the present invention discloses systems for moving coiled tubing in a wellbore, the wellbore extending from an earth surface down into the earth, the systems including movement apparatus for moving the coiled tubing into the wellbore, and vibration apparatus at the surface for vibrating the coiled tubing.

In one aspect, vibration is induced in the CT with a CTO system by pulsing hydraulic pressure to an injector's drive motors. This pulsation is created with a new injector drive system and/or the drive system hydraulics. In certain prior art injector drive systems the hydraulic power often have a positive displacement hydraulic pump driving positive displacement hydraulic motors, and undesirable vibration is often inherent in such systems. In these prior art systems efforts are made to avoid vibration. In some aspects of the present invention vibrations purposely induced and controlled. In one aspect a CT arch is used to absorb the vibration of the CT above the injector.

Alternatively, in certain aspects of the present invention, vibration is induced by adding vibration capability to the injector which moves the portion of the injector which is holding the CT. This vibration capability, in one aspect, is mechanical, such as an off balance rotating weight, hydraulic, pneumatic or electrically powered. In certain aspects, a drive section of an injector is rotated to achieve desired vibration of coiled tubing.
Alternatively, in certain aspects of the present invention, vibration is induced in CT by adding vibration capability to the well control stack, below the injector. This vibration is, in one aspect, transmitted through the injector to the CT, or is transmitted to the CT through contact with the CT in the well control stack. This vibration capability is, in one aspect, mechanical, such as an off balance rotating weight, hydraulic, pneumatic or electrically powered.

Alternatively, in certain aspects of the present invention, vibration is induced in CT by adding vibration capability to the support structure which holds the CT injector and/or the control stack. Many types of support structures are used, including a crane holding the injector from above, frame structures supporting the injector and control stack from below.

By reducing friction with system(s) and/or method(s) according to the present invention more accurate determinations of weight-on-bit (“WOB”) measurements can be accomplished and desired WOB can be achieved. In certain prior art coiled tubing systems, buckling and helical lockup—both caused primarily by friction—limit the amount of WOB that can be applied. A phenomenon known as “stick-slip” can occur when static (or stationary) friction is higher than dynamic (or moving) friction. When the WOB becomes too low, the CT is moved in the well slowly at the surface. Initially the CT and a BHA which are lower in the well stick, and then suddenly surge forward or slip. This surge forward can increase the WOB too much and cause a drilling motor in the BHA to stall. In one aspect, the present invention discloses methods for controlling weight-on-bit on a bit of a wellbore drilling system drilling a wellbore, the wellbore drilling system using a bit on a coiled tubing string for drilling, the wellbore extending from an earth surface down into the earth, the method including reducing friction between the coiled tubing string and the wellbore by vibrating the coiled tubing string with a vibratory system, thereby promoting free movement of the coiled tubing string and of the bit through the wellbore during drilling, the vibratory system comprising a movement apparatus for moving the coiled tubing string in the wellbore, and vibration apparatus at the surface for vibrating the coiled tubing. Any system(s) and method(s) according to the present invention can be used to reduce friction between coiled tubing and a wellbore and, in certain particular aspects, to sufficiently vibrate stuck coiled tubing to free it within a wellbore.

DESCRIPTION OF THE DRAWINGS

A more particular description of embodiments of the invention briefly summarized above may be had by references to the embodiments that are shown in the drawings which form a part of this specification. These drawings illustrate certain preferred embodiments and are not to be used to improperly limit the scope of the invention that may have other equally effective or legally equivalent embodiments.

FIGS. 1-2 are schematic views of prior art systems.

FIGS. 3-5 are schematic views of systems according to the present invention.

FIGS. 6-8 are schematic views of methods according to the present invention.

A system 300 according to the present invention as shown in FIG. 3 has a contra-rotating chain injector with vertical vibration capability. The injector has an outer support frame 303 with an optional guide arch 313. Inside the support frame 303 there is a CT drive section 304 which contains two contra-rotating chains 305. These chains 305 pass around sprockets 302. The chains 305 are clamped against CT 312 throughout the length between the sprockets 302, this length shown as 306. A clamping system 321 is shown schematically. This clamping force holds the CT between the chains 305. The chains are then rotated by a drive system 320 (shown schematically) which turns the sprockets 302. One chain turns in one direction (clockwise or counter clockwise) and the other chain turns in the opposite direction (i.e., they are contra-rotating). As the chains turn, the CT 312 moves in our out of the well. A single or a plurality of hydraulic cylinders 307 provide vibration by moving the inner drive section 304 of the injector up and down vertically with respect to the frame 303. This vertical movement of the inner section 304 moves the CT 312 and is absorbed in the CT arch 310. Guided supports 301 support the inner drive section 304 to prevent it from moving horizontally, while allowing it to move vertically. Hydraulic pressure is supplied to the vibration cylinders 307 by a vibration control unit 308 through hydraulic hosing 309.

A system 400 according to the present invention as shown in FIG. 4 has a contra-rotating chain injector with rotational vibration capability (like numerals in the Figures indicate parts). A single or a plurality of hydraulic motors 414 drive a pinion gear 413 which drives a ring gear 410 which is attached to the CT drive section 304 via a cylindrical support 407. Hydraulic pressure is provided by a vibration control unit 408 through hosing 409. The hydraulic motor through this gear system provides the vibration capability by moving the inner drive section of the injector 304 rotationally with respect to the frame 303. This rotational movement of the inner section 304 moves the CT 312 and is absorbed in the CT arch 310. Guided supports 401 support the inner drive section 304 to prevent it from moving horizontally or vertically, while allowing it to move rotationally. Hydraulic pressure is supplied to the motors 414 by a vibration control unit 408 through hydraulic hosing 409.

FIG. 5 shows a system 500 according to the present invention which has an axial vibrator placed at a location in the well control stack 105 (e.g., as shown in FIGS. 1 and 2). The vibrator has a lower cylindrical section 504 and an upper cylindrical piston 501. The CT 312 passes through the center of the stack. Seals 502 prevent hydraulic fluid from leaking from a pressure chamber 503. Hydraulic pressure is supplied to the cylindrical pressure chamber 504 by a vibration control unit 505 through hydraulic hosing 509.

FIG. 6 shows a system 600 according to the present invention which has a driven-roller injector, with vibration capability. This injector is smaller than certain contra-rotating types of injectors and is, therefore, easier to vibrate. The injector has an outer support frame 603 with an optional guide arch 313. Inside the support frame 602 there
is a CT drive section 604 which contains the driven rollers 602 driven by a drive section 611 shown schematically. As the rollers turn, the CT 312 moves in our out of the well. A single or a plurality of hydraulic cylinders 607 provide vibration by moving the inner drive section of the injector 604 up and down vertically with respect to the frame 603. This vertical movement of the inner section 604 moves the CT 312 and is absorbed in the CT arch 310. Guided supports 601 support the inner drive section 604 to prevent it from moving horizontally, while allowing it to move vertically. Hydraulic pressure is supplied to the vibration cylinders 607 by a vibration control unit 608 through hydraulic hosing 609.

[0025] FIG. 7 shows a system 700 according to the present invention like that of FIG. 6, but which has a driven roller injector with rotational vibration capability. A single or a plurality of hydraulic motors 714 drive a pinion gear 713 which drives a ring gear 710 which is attached to the CT drive section 604 via the cylindrical support 707. The hydraulic motor through this gear system provides vibration by moving the inner drive section of the injector 604 rotationally with respect to the frame 603. This rotational movement of the inner section 604 moves the CT 312 and is absorbed in the CT arch 310. Guided supports 701 support the inner drive section 604 to prevent it from moving horizontally or vertically, while allowing it to move rotationally. Hydraulic pressure is supplied to the motors 714 by a vibration control unit 708 through hydraulic hosing 709. FIG. 8 shows a system 800 according to the present invention which has an hydraulically driven injector 814 with axial vibration capability via an hydraulic power system. An hydraulic power supply 801 provides hydraulic power through hosing 802 to a vibration control system 803. The vibration control system 803 provides hydraulic power pulses through the hosing 804 to the injector 814. The pulsing hydraulic pressure vibrates the injector 814 and thus the CT 312 is vibrated. This axial vibration is absorbed by the CT arch 310 and passed through a control stack 815 into a well 806.

[0026] Any vibration apparatus according to the present invention may be used with vibration apparatus which is located within a wellbore (e.g., with the apparatus 311, FIG. 2).

[0027] U.S. Pat. No. 6,321,596, co-owned with the present invention, discloses systems and methods for measuring and controlling rotation of coiled tubing and claims apparatuses and methods for calculating and determining fatigue life of coiled tubing. System(s) and method(s) according to the present invention for rotation of coiled tubing can be used in the apparatuses and methods of U.S. Pat. No. 6,321,596 to provide rotation of coiled tubing.

[0028] The present invention, therefore, provides, in at least certain embodiments, methods for emplacing coiled tubing in a wellbore, the methods including moving coiled tubing in a wellbore in the earth, the wellbore extending from the earth surface down into the earth, and vibrating the coiled tubing as it is moved in the wellbore to reduce friction between the coiled tubing and the wellbore. Such method may include one or some, in any possible combination, of the following: wherein the coiled tubing is injected into the wellbore with an injector system, the injector system including vibrating apparatus for vibrating the injector system to thereby vibrate the coiled tubing, the method further including injecting the coiled tubing in the wellbore with the injector system, and vibrating the injector system with the vibrating apparatus to vibrate the coiled tubing; wherein the injector system includes a drive section for moving the coiled tubing through the injector system and the vibrating apparatus vibrates the drive section vertically, the method further including driving the coiled tubing with the drive section to move the coiled tubing in the wellbore, and vibrating the drive section vertically to vibrate the coiled tubing; wherein the injector system includes a drive section for moving the coiled tubing through the injector and the vibrating apparatus vibrates the drive section vertically, the method further including driving the coiled tubing with the drive section to move the coiled tubing in the wellbore, and vibrating the drive section vertically to vibrate the coiled tubing; wherein the injector system is a contra-rotating chain injector system; wherein the injector system is a drive roller injector system; wherein a stack is positioned at the surface of the earth and the coiled tubing is movable through the stack, the stack including stack vibrating apparatus for vibrating the coiled tubing, the method further including moving the coiled tubing through the stack, and vibrating the coiled tubing with the stack vibrating apparatus; wherein the stack vibrating apparatus includes hydraulic piston/cylinder apparatus for vibrating the coiled tubing; wherein movement apparatus is provided for moving the coiled tubing in the wellbore, and hydraulic power apparatus is connected to the movement apparatus, the method further including providing with the hydraulic power apparatus power in pulses to vibrate the coiled tubing; and/or vibrating the coiled tubing with vibrating apparatus within the wellbore.

[0029] The present invention, therefore, provides in at least certain embodiments, systems for moving coiled tubing in a wellbore, the wellbore extending from an earth surface down into the earth, the systems including movement apparatus for moving the coiled tubing in the wellbore, and vibration apparatus at the surface for vibrating the coiled tubing. Such systems may have one or some, in any possible combination, of the following: the movement apparatus including an injector system for injecting the coiled tubing into the wellbore, the injector system including vibrating apparatus for vibrating the injector system to thereby vibrate the coiled tubing; wherein the injector system includes a drive section for moving the coiled tubing through the injector and the vibrating apparatus vibrates the drive section vertically wherein the injector system includes a drive section for moving the coiled tubing through the injector and the vibrating apparatus vibrates the drive section vertically wherein the injector system is a contra-rotating chain injector system; wherein the injector system is a drive roller injector system; a stack at the surface through which the coiled tubing is movable, and the stack including stack vibrating apparatus for vibrating the coiled tubing; hydraulic power apparatus connected to the movement apparatus, the hydraulic power apparatus for providing pulses of
power to vibrate the coiled tubing; and/or wellbore vibrating apparatus within the wellbore for vibrating the coiled tubing.

[0030] The present invention, therefore, in at least certain embodiments, provides methods for controlling weight-on-bit on a bit of a bottom hole assembly of a wellbore drilling system drilling a wellbore, the wellbore drilling system using a bit on a coiled tubing string for drilling, the wellbore extending from an earth surface down into the earth, the method including reducing friction between the coiled tubing string and the wellbore by vibrating the coiled tubing string with a vibratory system, thereby promoting free movement of the coiled tubing string and/or of the bit and bottom hole assembly through the wellbore during drilling, the vibratory system like any disclosed herein according to the present invention, e.g. including a movement apparatus for moving the coiled tubing string in the wellbore, and vibration apparatus at the surface for vibrating the coiled tubing; and in none aspect such a method for promoting free movement of all of the coiled tubing, the bit and the bottom hole assembly.

[0031] All patents referred to herein by number are incorporated fully herein for all purposes. In conclusion, therefore, it is seen that the present invention and the embodiments disclosed herein and those covered by the appended claims are well adapted to carry out the objectives and obtain the ends set forth. Certain changes can be made in the subject matter without departing from the spirit and the scope of this invention. It is realized that changes are possible within the scope of this invention and it is further intended that each element or step recited in any of the following claims is to be understood as referring to all equivalent elements or steps. The following claims are intended to cover the invention as broadly as legally possible in whatever form it may be utilized. The invention claimed herein is new and novel in accordance with 35 U.S.C. § 102 and satisfies the conditions for patentability in § 102. The invention claimed herein is not obvious in accordance with 35 U.S.C. § 103 and satisfies the conditions for patentability in § 103. This specification and the claims that follow are in accordance with all of the requirements of 35 U.S.C. § 112. The inventors may rely on the Doctrine of Equivalents to determine and assess the scope of their invention and of the claims that follow as they may pertain to apparatus not materially departing from, but outside of, the literal scope of the invention as set forth in the following claims.

What is claimed is:

1. A method for emplacing coiled tubing in a wellbore, the method comprising

   moving coiled tubing in a wellbore in the earth, the wellbore extending from the earth surface down into the earth, and

   vibrating the coiled tubing with vibrating apparatus at the surface as the coiled tubing is moved in the wellbore to reduce friction between the coiled tubing and the wellbore.

2. The method of claim 1 wherein the coiled tubing is injected into the wellbore with an injector system, the injector system including vibrating apparatus for vibrating the injector system to thereby vibrate the coiled tubing, the method further comprising

   injecting the coiled tubing in the wellbore with the injector system, and

   vibrating the injector system with the vibrating apparatus to vibrate the coiled tubing.

3. The method of claim 2 wherein the injector system includes a drive section for moving the coiled tubing through the injector system and the vibrating apparatus vibrates the drive section vertically, the method further comprising

   driving the coiled tubing with the drive section to move the coiled tubing in the wellbore, and

   vibrating the drive section vertically to vibrate the coiled tubing.

4. The method of claim 2 wherein the injector system includes a drive section for moving the coiled tubing through the injector and the vibrating apparatus vibrates the drive section vertically, the method further comprising

   driving the coiled tubing with the drive section to move the coiled tubing in the wellbore, and

   vibrating the drive section vertically to vibrate the coiled tubing.

5. The method of claim 2 wherein the injector system includes a drive section for moving the coiled tubing through the injector and the vibrating apparatus rotates the drive section to vibrate the drive section, the method further comprising

   driving the coiled tubing with the drive section to move the coiled tubing in the wellbore, and

   rotating the drive section to vibrate the coiled tubing.

6. The method of claim 2 wherein the injector system is a contra-rotating chain injector system.

7. The method of claim 2 wherein the injector system is a driven roller injector system.

8. The method of claim 1 wherein a stack is positioned at the surface of the earth and the coiled tubing is movable through the stack, the stack including stack vibrating apparatus for vibrating the coiled tubing, the method further comprising

   moving the coiled tubing through the stack, and

   vibrating the coiled tubing with the stack vibrating apparatus.

9. The method of claim 7 wherein the stack vibrating apparatus includes hydraulic piston/cylinder apparatus for vibrating the coiled tubing.

10. The method of claim 1 wherein movement apparatus is provided for moving the coiled tubing in the wellbore, and hydraulic power apparatus is connected to the movement apparatus, the method further comprising

    providing with the hydraulic power apparatus power in pulses to vibrate the coiled tubing.

11. The method of claim 1 further comprising vibrating the coiled tubing with vibrating apparatus within the wellbore.

12. A system for moving coiled tubing in a wellbore, the wellbore extending from an earth surface down into the earth, the system comprising

    movement apparatus for moving the coiled tubing into the wellbore, and
vibration apparatus at the surface for vibrating the coiled tubing.

13. The system of claim 12 wherein
the movement apparatus includes an injector system for
injecting the coiled tubing into the wellbore,
the injector system including vibrating apparatus for
vibrating the injector system to thereby vibrate the
coiled tubing.

14. The system of claim 13 wherein the injector system
includes a drive section for moving the coiled tubing
through the injector and the vibrating apparatus vibrates the
drive section vertically.

15. The system of claim 13 wherein the injector system
includes a drive section for moving the coiled tubing
through the injector and the vibrating apparatus rotates the
drive section to vibrate the coiled tubing.

16. The system of claim 13 wherein the injector system is
a contra-rotating chain injector system.

17. The system of claim 13 wherein the injector system is
driven roller injector system.

18. The system of claim 12 further comprising
a stack at the surface through which the coiled tubing is
movable, and
the stack including stack vibrating apparatus for vibrating
the coiled tubing.

19. The system of claim 12 further comprising
hydraulic power apparatus connected to the movement
apparatus, the hydraulic power apparatus for providing
pulses of power to vibrate the coiled tubing.

20. The system of claim 12 further comprising wellbore
vibrating apparatus within the wellbore for vibrating the
coiled tubing.

21. A method for controlling weight-on-bit on a bottom
hole assembly of a wellbore drilling system drilling a
wellbore, the wellbore drilling system using a bottom hole
assembly and bit on a coiled tubing string for drilling, the
wellbore extending from an earth surface down into the
earth, the method comprising
reducing friction between the coiled tubing string and the
wellbore by vibrating the coiled tubing string with a
vibratory system, thereby promoting free movement of
the coiled tubing string through the wellbore during
drilling,
the vibratory system comprising a movement apparatus
for moving the coiled tubing string in the wellbore, and
vibration apparatus at the surface for vibrating the
coiled tubing.

22. The method of claim 21 wherein said vibrating
promotes movement of the bit and of the bottom hole
assembly through the wellbore during drilling

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