SYSTEM, METHOD AND APPARATUS FOR DRILLING AGITATOR

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ABSTRACT

A drilling agitator tool, system and method facilitates axial movement of a drill string in a well. The tool has a valve assembly that provides pulses of fluid pressure in the drill string. A valve control assembly controls a frequency and pressure amplitude of the pulses induced by the valve assembly. The valve control assembly monitors real-time pressure and vibration levels of the drill string. An agitator assembly reciprocates in response to the pulses of fluid pressure to provide axial movement of the drill string in the well.
POWER ON 901

DIAGNOSTIC CHECK 903

IS FLOW ON?

NO → WAIT - MONITOR INCLINATION OF TOOL POWER SAVE MODE 907

YES → INITIATE VALVE FUNCTION AT 20 Hz 909

MEASURE SHOCK, VIBRATION AND DIFFERENTIAL PRESSURE

ARE MEASUREMENTS BELOW ACCEPTABLE RANGE?

NO → STORE DATA 913

YES → DECREASE VALVE FREQUENCY BY 1 Hz 921

ARE LEVELS ABOVE ACCEPTABLE RANGE?

NO → STORE DATA 927

YES → INCREASE VALVE FREQUENCY BY 1 Hz 919

IS FLOW ON?

NO → MAINTAIN VALVE OPERATION - MEASURE SHOCK, VIBRATION AND DIFFERENTIAL PRESSURE 925

FIG. 9
SYSTEM, METHOD AND APPARATUS FOR DRILLING AGITATOR

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Disclosure

[0002] The present invention relates in general to drilling oil and gas wells and, in particular, to a system, method and apparatus for facilitating axial movement of a drill string while it is drilling a well.

[0003] 2. Description of the Related Art

[0004] Some oil and gas well bore profiles focus on horizontal well bore sections that increase the interface or surface area with the producing formation. As the length of the horizontal section increases, steps must be taken to reduce the friction or sticking force on the drill string. It is desirable to minimize these forces by maintaining the string in a dynamic mode as it moves axially through the well.

[0005] The friction problem is further acerbated when a directional drilling assembly is used in a steering mode. During steering mode, the drill string is typically held in a relatively stationary orientation as weight is applied and only the bit is rotated. When hole friction is significant, the weight added at the surface of the well is not immediately realized at the drill bit until the friction force is overcome. At that point, the sudden increase of weight at the bit can cause the mud motor to stall, forcing the operator to pick up and remove a portion of the weight. In these conditions, it has proven beneficial to have a device that induces vibration, a hammering effect or a reciprocating drilling tool to keep the drill string in a dynamic mode even when it is not rotated.

[0006] Various concepts have been used to agitate drill strings, most of which are actuated by the mud flow to the bit. As the drilling conditions change (e.g., weight on bit, mud flow rate, formation, bit type, etc.) these agitation tools are unable to compensate. Some devices generate severe vibrations at resonating frequencies that cause costly premature failures of other down hole equipment, such as measurement while drilling (MWD) equipment. Most agitation tools are controlled only by the mud flow rate and differential pressure that they experience down hole. Various setups can be installed when the agitation tool is serviced, but cannot be changed once the tool is in the field.

[0007] It would be desirable to have an agitation tool that automatically monitors its performance and makes the necessary adjustments as agitation levels approach detrimental or severe conditions. Ideally, such a tool would provide real time monitoring and control of its function even as drilling conditions change.

SUMMARY

[0008] Embodiments of a system, method and apparatus for facilitating axial movement of a drill string while it is drilling a well are disclosed. In some embodiments, the drilling agitator for a drill string in a well comprises a valve assembly that provides pulses of fluid pressure in the drill string. A valve control assembly controls a frequency and pressure amplitude of the pulses induced by the valve assembly. The valve control assembly monitors real-time pressure and vibration levels of the drill string. An agitator assembly reciprocates in response to the pulses of fluid pressure to provide axial movement of the drill string in the well.

[0009] Embodiments of a system for facilitating axial movement in a well comprises a drill string having a drill bit and a drilling agitator as described herein. Embodiments of method of facilitating axial movement of a drill string while drilling a well comprises operating a drill string in a well in a dynamic mode; detecting an axial acceleration of the drill string and, if the axial acceleration is insufficient or the vibration is excessive, pulsing fluid pressure in the drill string between a normal circulation pressure and an elevated or lower pressure; reciprocating an agitator in response to the pulsing fluid pressure to facilitate axial movement of the drill string in the well.

[0010] The foregoing and other objects and advantages of these embodiments will be apparent to those of ordinary skill in the art in view of the following detailed description, taken in conjunction with the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] So that the manner in which the features and advantages of the embodiments are attained and can be understood in more detail, a more particular description may be had by reference to the embodiments thereof that are illustrated in the appended drawings. However, the drawings illustrate only some embodiments and therefore are not to be considered limiting in scope as there may be other equally effective embodiments.

[0012] FIG. 1 is a schematic diagram of an embodiment of a drill string and agitator tool in a well;

[0013] FIG. 2 is an exploded, partially sectioned isometric view of an embodiment of the agitator tool of FIG. 1;

[0014] FIG. 3 is a sectional side view of an embodiment of a valve control assembly for an agitator tool;

[0015] FIG. 4 is an enlarged sectional side view of an embodiment of a valve assembly for an agitator tool;

[0016] FIG. 5 is an enlarged sectional side view of an embodiment of a servo valve assembly for an agitator tool;

[0017] FIG. 6 is an enlarged sectional side view of an embodiment of a valve assembly with the valve extended;

[0018] FIG. 7 is an enlarged sectional side view of an embodiment of a valve assembly with the valve retracted;

[0019] FIG. 8 is a sectional side view of an embodiment of an agitator assembly for an agitator tool; and

[0020] FIG. 9 is a high level flow diagram of an embodiment of a control method.

[0021] The use of the same reference symbols in different drawings indicates similar or identical items.

DETAILED DESCRIPTION

[0022] Embodiments of a system, method and apparatus for facilitating axial movement of a drill string while it is drilling a well are disclosed. It is desirable to maintain movement in a drill string during its operation since the dynamic friction force is substantially less than the static friction force. As horizontal sections of current oil and gas wells increase, the incurred friction forces hamper and affect efficient drilling operations. One method for maintaining continuous movement of the drill string is to utilize a shock tool as an agitating device that is driven by a cyclic pressure wave. The shock tool has an incorporated seal surface that can be extended as pressure increases. The shock tool or agitator contracts when the pressure level decreases.

[0023] The frequency and duration of these pressure fluctuations determines the displacement and acceleration of the shock tool. It is desirable that the movements of the shock tool
are controlled to prevent damage to the drilling assembly while optimizing the penetration rate of the assembly.

A valve mechanism may be used to create and control these pressure cycles. The valve mechanism restricts the flow rate past this section of the drill string creating the desired pressure fluctuations. The valve can contain various measurement devices that monitor the amplitude of the pressure cycles, the shock levels generated by the shock tool or agitator, and the frequency of the vibration experienced by the drilling assembly. These measurements can then be compared to acceptable and desired ranges. The controlling electronics for the valve mechanism then adjusts the frequency and duration of the pressure cycles to achieve and maintain the desired effects for efficient drilling operations.

One or more agitators or shock tools can be placed above and/or below the valve mechanism. Various lengths of drill pipe can also be used to separate the agitators from the valve mechanism. In one embodiment, the agitator is located directly above the valve mechanism. An alternative embodiment adds a second agitator below the valve mechanism. The agitators complement the movements of each other. The agitator above the valve mechanism expends as it experiences a pressure increase. The second agitator below the valve mechanism experiences a pressure decrease and contracts, allowing the upper agitator to expand more readily. By increasing the distance between the two agitators, a greater mass of drill string is moved thereby increasing the momentum. As one can appreciate the greater the distance between the agitators, the lower the required frequency of the valve mechanism.

Various valve mechanisms can be used to create the cyclic pressure wave. One style utilizes a series of turbine style blades stacked above each other. The top set of blades is typically stationary and causes a change in the trajectory of the mud flow. The next row of blades is curved in a reverse pattern and rotates about the axial axis. The rotating band of blades can be controlled (e.g., braked) to slow or even momentarily stop to create the pressure increase.

Another valve style causes a flow area restriction through an orifice. A plunger or poppet is allowed to enter the orifice decreasing the flow area momentarily. Various drive mechanisms for this plunger can be used. Electrical control of the plunger is beneficial to allow for frequency changes in the pressure wave. As stated previously the frequency and duration of the pressure cycles control the amount of drill string agitation. In still other embodiments, negative pressure pulses also may be used to accomplish the desired agitation. For example, fluid may be cyclically ported through the side of the drill string to form pressure decreases rather than increases.

FIG. 1 depicts an embodiment of a down hole agitator tool 21 for use in a drill string 22 while drilling a well. The tool 21 may be located behind the drill bit 23 and steering assembly 24. Drilling fluid or mud is circulated through the interior of the drill string 22. As shown in FIG. 2, the tool 21 comprises a number of elements that are rigidly secured to one another. The drilling fluid flows through the internal bore of the agitator assembly 25 and continues past a valve assembly 26 in the annulus formed between these components and their pipes or external housing 27. Housing 27 is a generally cylindrical, hollow body having two threaded body components (FIG. 2), in some embodiments. The tool 21 may be powered by a battery 28 and have control electronics 29. The valve assembly 26 forms pressure pulses in the stream of drilling fluid circulated in the annulus in response to digital signals provided by the control electronics 29.

In the embodiment of FIGS. 3 and 4, a lower end of valve assembly 26 lands on a shoulder of a flow sleeve 30 positioned in a muleshoesub 38. A signal poppet or shaft 33 is generally carried within a lower valve body 31 or orienting sleeve that fits securely within muleshoe sub 38. Signal poppet 33 has a lower end or poppet tip 37 and is axially movable within valve body 31 relative to an orifice 32. Lower end 37 has an extended position (FIG. 6) that restricts fluid flow, and a retracted position (FIG. 7) that permits the free flow of fluid.

As shown by the flow arrows of FIG. 4, the orifice 32 is positioned to allow axial flow of the drilling fluid from the annulus. In one embodiment, orifice 32 is positioned axially below lower end 37 of signal poppet 33. Orifice 32 may comprise an upper orifice sleeve and the flow sleeve 30. The upper orifice sleeve may be provided with a taper 36 or inclined surface toward its upper end. The inner diameter of the uppermost portion of orifice 32 is greater than the inner diameter at the lower end of the inclined surface.

As signal shaft 33 moves from its retracted position to the extended position, lower end 37 of signal poppet 33 helps restrict the flow of drilling fluid from the annulus through orifice 32 by narrowing the effective diameter of orifice 32. In some embodiments, a spring 35 (FIG. 4) is situated axially above signal shaft 33 to bias signal shaft 33 axially downward toward orifice 32. A poppet stop 97 is positioned axially above signal shaft 33 within spring 35 to limit the axially upward movement of signal shaft 33 as it moves between the retracted and extended positions.

A fluid path 40 (FIG. 4) extends through a side portion of the lower segment of flow sleeve 30 such that drilling fluid flows from the annulus to the orifice 32. In the embodiment shown, the lower end 37 of signal poppet 33 is positioned in the flow path 40. A lower inner passage 34 or bore extends axially through signal poppet 33 from an opening formed in lower end 37 and continuing through poppet stop 97. A seal member 95 is positioned between an upper valve body 96 and an upper end portion of signal poppet 33 such that drilling fluid exiting an upper inner passage 51 in the valve assembly is forced to enter lower inner passage 34.

As will be appreciated by those skilled in the art, seal member 95 engages an outer surface of signal poppet 33 and an interior surface of upper valve body 96. In the embodiment of FIG. 5, upper inner passage 51 extends axially through a valve seat 72 positioned axially above poppet stop 97. Valve seat 72 is in fluid communication with lower inner passage 34. Upper inner passage 51 extends axially through valve seat 72 and opens into a valve chamber 70. Valve chamber 70 houses a lower end portion of a servo valve assembly 61.

Embodiments of servo valve assembly 61 include a servo shaft 93 extending axially upward and away from valve seat 72. Servo shaft 93 extends axially through a bore of an evacuation sub 60 (FIG. 4) that defines an upper wall of valve chamber 70. The servo shaft 93 is coupled to servo tip 69 at a lower end. Servo shaft 93 is axially movable through evacuation sub 60 such that servo tip 69 engages an upper surface of valve seat 72 to block the fluid flow from valve chamber 70 to upper inner passage 51. When servo shaft 93 is in a retracted position, servo tip 69 is removed from valve seat 72 to permit flow of drilling fluid from valve chamber 70 into upper inner passage 51.
In some embodiments, a plurality of servo bellows extend from an outer surface of evacuation sub to an outer surface of servo shaft that receives servo shaft. Valve chamber may include an opening formed in a side of a valve body. A servo screen is positioned across the opening formed in valve body for protecting servo valve assembly from debris located outside of valve body. A plurality of ports extends through servo screen. Drilling fluid fills the ports into valve chamber from the annulus when servo shaft is in the extended or closed position (FIG. 7), and out of valve chamber when servo shaft is in the refracted position (FIG. 6).

In operation, when servo shaft is extended axially downward to its closed position (FIG. 7), the servo tip blocks the flow of drilling fluid through opening 72 from valve chamber 70. This provides an upward pressure against signal poppet that compresses spring and allows drilling fluid to flow through passage in an unrestricted manner. When servo shaft is actuated axially upward (FIG. 6), the servo tip allows drilling fluid to flow through the ports of servo screen 73, into valve chamber 70 and out valve seat 72 into upper inner passage 51. The fluid pressure increases in upper inner passage 51 which assists spring to move signal poppet axially downward to restrict flow through orifice 32, and thereby form a pressure pulse.

A stationary spacer is positioned axially above evacuation sub and receives an upper portion of servo shaft. In some embodiments, servo shaft extends axially through stationary spacer to a ramp mechanism positioned at an axially opposite position from evacuation sub. Ramp mechanism may be provided with a bore formed in a lower central portion for receiving servo shaft. Ramp mechanism is preferably attached to servo shaft with threaded connections. As will be appreciated by those skilled in the art, the ramp mechanism axially moves the servo shaft between its extended and retracted positions relative to valve seat and upper inner passage. Ramp mechanism advantageously acts to limit the axially downward movement of servo shaft and servo tip relative to valve seat by engaging an upper end portion of stationary spacer when servo shaft moves axially downward into engagement with valve seat.

The outer portion of the ramp mechanism is prevented from rotating with respect to assembly by a retaining ring 59, but can be moved axially when the impeller rotates. As impeller rotates it contacts the inner ramp profile of the ramp mechanism causing it to move axially upward. A return spring causes axial movement downward to complete the movement of the servo shaft. The impeller is rotated by the motor/gear box assembly via a coupler. In operation, motor/gear box assembly is actuated to rotate the impeller via coupler. Ramp mechanism translates rotational movement from impeller into axial movement that is imparted upon servo valve assembly, causing the upward and downward movement relative to valve seat. The control of the motor/gear box assembly may, in turn, control the frequency and duration of the axial movement.

In some embodiments, a circuit may include accelerometers on one, two or three axes to monitor acceleration. There will be an optimum level of axial acceleration that is desirable to the drilling operation. Circuit uses data, such as the accelerometers to determine the optimum rotational speed of the motor/gear box assembly. As will be appreciated by those skilled in the art, a decrease in rotational speed induces a slower cycle in pressure but increases the amplitude of the pressure wave. The increased pressure amplitude causes an increase in axial acceleration and movement of the agitator assembly and subsequently in the drill string (FIG. 1).

In some embodiments, there is a point at which the pressure amplitude is too large which creates significant axial acceleration (e.g., excess vibration) of the drill string. The circuit monitors and controls the frequency of the pressure cycles and in turn the magnitude of the axial acceleration experienced by the drill string.

The momentary flow restrictions induce pressure increases or pulses. Referring to FIG. 8, the agitator assembly contains a center mandrel that is loosely coupled to the outer housing. A spring allows the mandrel to contract into the outer housing while compressing spring. Conversely, a disc spring allows the mandrel to extend out from the outer housing while compressing disc spring. A sealed volume of oil between the inner surface of outer housing and the outer surface of mandrel provides lubrication of the contained components.

Drilling fluid flows down through an inner diameter bore of the mandrel, which is threaded to a compensation mandrel. A hole extends through the wall of compensation mandrel at the outer end to allow drilling fluid to enter the bore on the top side of compensation piston. The drilling fluid pressure acts on the top side of compensation piston to ensure the oil volume is maintained at the same pressure as the drilling fluid.

The cross-sectional area where the seals slide on the outer surface of the mandrel provides a hydraulic piston area. As the drilling fluid pressure increases, this added hydraulic pressure acts on mandrel to induce a force that tends to extend the mandrel out of the housing. Conversely, during a pressure decrease of the drilling fluid, the hydraulic force decreases, allowing the mandrel to contract into the housing. The pressure increase and decrease caused by the valve assembly induces the extension and contraction of the agitator assembly.

In some embodiments, the device has a valve assembly that provides momentary positive mud pressure increases in the drill string above the drill bit. After the pressure increase is generated by restricting the flow of mud, the valve releases the restriction and the pressure drops back to the normal circulation pressure. This cyclic pressure increase and decrease drives a reciprocating device or agitator assembly to facilitate axial movement of the drill string in the well. The increased pressure causes an increase in the length of the agitator assembly due to the pressure differential between the internal pressure and the external or annulus pressure. For example, the agitator may be capable of up to about three inches of axial movement, but in operation may only oscillate about one-eighth to one inch.
The frequency (e.g., about 5 to 40 Hz) and pressure amplitude of the valve assembly is controlled by an electronic circuit that monitors real-time pressure and vibration levels downhole. For example, an embodiment of a high level flow diagram of a control system is depicted in FIG. 9. After power is supplied (block 901) and a diagnostic check (block 903) is performed, a determination is made (block 905) as to whether fluid is flowing through the tool. If no fluid is flowing, the inclination of the downhole tool is monitored in a power saving mode (block 907). As fluid flows and the tool operates, the circuit samples and compares the pressure and vibration levels to preprogrammed ranges. The valve is initially controlled to operate at a preset speed (about 20 Hz, for example, as shown in block 909). Shock, vibration and differential pressure are monitored (block 911) and the data is stored (block 913). A determination is made whether these measurements are below (block 915) or above (block 917) an acceptable range. If either the pressure or vibration level is above the acceptable range, the valve speed is increased (such as by 1 Hz) to lower these levels (block 919). If one or more of the levels are below the desired range (block 921) the valve speed is decreased (such as by 1 Hz). As fluid continues to flow (block 923) this sequence is repeated until both values for vibration level and differential pressure are within the pre-programmed ranges (block 925) and the data is stored (block 927). As drilling conditions change the circuit automatically adjusts the valve control to maintain the optimum performance. The system is self-contained with its own battery source that drives the circuit and motor assembly to control the flow restriction valve.

In some embodiments, the drilling agitator for a drill string in a well comprises a valve assembly that provides pulses of fluid pressure in the drill string. A valve control assembly controls a frequency and pressure amplitude of the pulses induced by the valve assembly. The valve control assembly monitors real-time pressure and vibration levels of the drill string. An agitator assembly reciprocates in response to the pulses of fluid pressure to provide axial movement of the drill string in the well.

The valve assembly may comprise a signal poppet that is axially movable within a valve body relative to an orifice. The signal poppet has an extended position that restricts but does not prevent fluid flow through the orifice, and a retracted position that permits the free flow of fluid through the orifice. The signal poppet may be spring-biased to the extended position, fluid flows between an exterior of the signal poppet and an interior of the orifice, and the signal poppet has a bore through which fluid flows.

The valve assembly may further comprise an upper inner passage that extends axially through a valve seat that is in fluid communication with the bore of the signal poppet. A servo valve assembly that opens and closes the valve seat to regulate fluid flow therebetween to actuate the signal poppet. The servo valve assembly may comprise a servo shaft extending through an evacuation sub, the servo shaft having a servo tip with a closed position for engaging the valve seat to block the fluid flow to the upper inner passage, and an open position wherein the servo tip is removed from the valve seat to permit fluid flow to the upper inner passage. The closed position may actuate the signal poppet to the retracted position. The open position may actuate the signal poppet to the extended positioned and thereby form a pressure pulse.

The valve seat may be located in a valve chamber having an opening for permitting fluid to enter the valve chamber from an annulus between the servo valve assembly and a housing thereof. The servo shaft may be coupled to a ramp to axially move the servo tip between the open and closed positions, the ramp being moved axially in one direction in response to rotation of an impeller by a motor, and in an opposite direction in response to a spring force.

Control of the motor controls the frequency and duration of the axial movement of the servo tip, and control is provided by a circuit to control a rotational speed of the impeller, and cyclic movement of the signal poppet in response thereto. The circuit may further comprise at least one accelerometer to monitor axial acceleration of the drill string to determine a desired rotational speed of the motor, wherein a decrease in rotational speed induces a slower cycle in pressure but increases pressure amplitude, which causes an increase in axial acceleration and movement of the agitator assembly and the drill string.

The agitator assembly may comprise a mandrel coupled to a housing, a spring for biasing the mandrel out of the housing, a disc spring for drawing the mandrel into the housing, a compensation piston coupled to the mandrel for circulating fluid thereto, the mandrel being responsive to the fluid pressure pulses to oscillate relative to the housing and axially move the drill string. In other embodiments, the agitator assembly comprises a plurality of agitator assemblies and the valve assembly is located axially between at least two of the agitator assemblies.

Embodiments of a system for facilitating axial movement in a well comprises a drill string having a drill bit and a drilling agitator as described herein. Embodiments of method of facilitating axial movement of a drill string while drilling a well comprises operating a drill string in a well in a dynamic mode; detecting an axial acceleration of the drill string and, if the axial acceleration is insufficient or the vibration is excessive, pulsing fluid pressure in the drill string between a normal circulation pressure and an elevated pressure or a lower pressure, respectively; reciprocating an agitator in response to the pulsing fluid pressure to facilitate axial movement of the drill string in the well. The dynamic mode may comprise drilling with a drill bit or steering the drill bit.

The method may further comprise determining a desired vibration level of the drill string by stepping through a series of preprogrammed increments of frequency and pressure amplitude for the pulsing fluid; operating the drill string at the desired vibration level; monitoring the axial acceleration of the drill string; and adjusting the vibration level to improve the axial acceleration of the drill string. The frequency may be about 5 to 40 Hz, and pressure amplitude of the valve assembly is controlled by an electronic circuit that monitors real-time pressure and vibration levels downhole. The frequency may be adjusted by about 1 Hz when the pressure or vibration level is above or below an acceptable range.

Embodiments of the agitation tool have numerous advantages, including reciprocating axial movement within the drill string to minimize adverse friction forces. The reciprocal motion does not hammer components together, and thereby avoids damage to sensitive electrical components as is common with conventional agitation tools. The tool monitors pressure and vibration amplitude down hole to aid with tool performance. A power save mode prevents the tool from operating until a pre-programmed condition exists. At startup, the tool steps through a series of pre-programmed increments of frequency and amplitude cycles to determine the optimum performance levels for that particular well applica-
tion. The tool controls the flow restriction within the drill string in a cyclic manner, and uses collected data to adjust flow restriction to optimize drilling performance. The Valve mechanism is a servo based system that reduces power consumption.

[0057] This written description uses examples to disclose the embodiments, including the best mode, and also to enable those of ordinary skill in the art to make and use the invention. The patentable scope is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

[0058] Note that not all of the activities described above in the general description or the examples are required, that a portion of a specific activity may not be required, and that one or more further activities may be performed in addition to those described. Still further, the order in which activities are listed are not necessarily the order in which they are performed.

[0059] In the foregoing specification, the concepts have been described with reference to specific embodiments. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the invention as set forth in the claims below. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of invention.

[0060] As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of features is not necessarily limited only to those features but may include other features not expressly listed or inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, “or” refers to an inclusive-or and not to an exclusive-or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

[0061] Also, the use of “a” or “an” are employed to describe elements and components described herein. This is done merely for convenience and to give a general sense of the scope of the invention. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

[0062] Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any feature(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature of any or all the claims.

[0063] After reading the specification, skilled artisans will appreciate that certain features are, for clarity, described herein in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features that are, for brevity, described in the context of a single embodiment, may also be provided separately or in any subcombination. Further, references to values stated in ranges include each and every value within that range.

What is claimed is:

1. A drilling agitator for a drill string in a well, comprising:
   a valve assembly that provides pulses of fluid pressure in the drill string:
   a valve control assembly that controls a frequency and pressure amplitude of the pulses induced by the valve assembly, and the valve control assembly monitors real-time pressure and vibration levels of the drill string; and
   an agitator assembly that reciprocates in response to the pulses of fluid pressure to provide axial movement of the drill string in the well.

2. A drilling agitator according to claim 1, wherein the valve assembly contains a servo shaft that is coupled to a ramp to axially move a servo tip between open and closed positions, the ramp being moved axially in one direction in response to rotation of an impeller by a motor, and in an opposite direction in response to a spring force.

3. A drilling agitator according to claim 2, wherein control of the motor controls the frequency and duration of the axial movement of the servo tip, and control is provided by a circuit to control a rotational speed of the impeller, and cyclic movement of the signal poppet in response thereto.

4. A drilling agitator according to claim 3, wherein the circuit further comprises at least one accelerometer to monitor axial acceleration of the drill string, wherein a decrease in rotational speed induces a slower cycle in pressure but increases pressure amplitude, which causes an increase in axial acceleration and movement of the agitator assembly and the drill string.

5. A drilling agitator according to claim 1, wherein the agitator assembly comprises a mandrel coupled to a housing, a spring for biasing the mandrel out of the housing, a disc spring for drawing the mandrel into the housing, a compensation piston coupled to the mandrel for circulating fluid thereto, the mandrel being responsive to the fluid pressure pulses to oscillate relative to the housing and axially move the drill string.

6. A drilling agitator according to claim 1, wherein the agitator assembly comprises a plurality of agitator assemblies and the valve assembly is located axially between at least two of the agitator assemblies.

7. A system for facilitating axial movement in a well, comprising:
   a drill string having a drill bit and a drilling agitator; the drilling agitator comprising:
   a valve assembly that provides pulses of fluid pressure increase in the drill string above the drill bit;
   a valve control assembly that controls a frequency and pressure amplitude of the pulses induced by the valve assembly, and the valve control assembly monitors real-time pressure and vibration levels of the drill string; and
   an agitator assembly that reciprocates in response to the pulses of fluid pressure to provide axial movement of the drill string in the well.

8. A system according to claim 7, wherein the valve assembly comprises a signal poppet that is axially movable within a valve body relative to an orifice, the signal poppet having an extended position that restricts but does not prevent fluid flow through the orifice, and a retracted position that permits the free flow of fluid through the orifice.

9. A system according to claim 8, wherein the signal poppet is spring-biased to the extended position, fluid flows between
an exterior of the signal poppet and an interior of the orifice, and the signal poppet has a bore through which fluid flows.

10. A system according to claim 9, wherein the valve assembly further comprises an upper inner passage that extends axially through the valve seat that is in fluid communication with the bore of the signal poppet, and a servo valve assembly that opens and closes the valve seat to regulate fluid flow therethrough to actuate the signal poppet.

11. A system according to claim 10, wherein the servo valve assembly comprises a servo shaft extending through an evacuation sub, the servo shaft having a servo tip with an closed position for engaging the valve seat to block the fluid flow to the upper inner passage, and an open position wherein the servo tip is removed from the valve seat to permit fluid flow to the upper inner passage.

12. A system according to claim 11, wherein the closed position actuates the signal poppet to the retracted position, and the open position actuates the signal poppet to the extended position and thereby form a pressure pulse.

13. A system according to claim 11, wherein the valve seat is located in a valve chamber having an opening for permitting fluid to enter the valve chamber from an annulus between the servo valve assembly and a housing thereof.

14. A system according to claim 11, wherein the servo shaft is coupled to a ramp to axially move the servo tip between the open and closed positions, the ramp being moved axially in one direction in response to rotation of an impeller by a motor, and in an opposite direction in response to a spring force.

15. A system according to claim 14, wherein control of the motor controls the frequency and duration of the axial movement of the servo tip, and control is provided by a circuit to control a rotational speed of the impeller, and cyclic movement of the signal poppet in response thereto.

16. A system according to claim 15, wherein the circuit further comprises at least one accelerometer to monitor axial acceleration of the drill string, wherein a decrease in rotational speed induces a slower cycle in pressure but increases pressure amplitude, which causes an increase in axial acceleration and movement of the agitator assembly and the drill string.

17. A system according to claim 7, wherein the agitator assembly comprises a mandrel coupled to a housing, a spring for biasing the mandrel out of the housing, a disc spring for drawing the mandrel into the housing, a compensation piston coupled to the mandrel for circulating fluid thereto, the mandrel being responsive to the fluid pressure pulses to oscillate relative to the housing and axially move the drill string.

18. A system according to claim 7, wherein the agitator assembly comprises a plurality of agitator assemblies and the valve assembly is located axially between at least two of the agitator assemblies.

19. A method of facilitating axial movement of a drill string while drilling a well, comprising:
   operating a drill string in a well in a dynamic mode;
   detecting an axial acceleration of the drill string and, if the axial acceleration is insufficient, pulsing fluid pressure in the drill string between a normal circulation pressure and an elevated pressure, and, in case of excessive and exaggerated fluid pressure in the drill string between the normal condition and a lower pressure; and
   reciprocating an agitator in response to the pulsing fluid pressure to facilitate axial movement of the drill string in the well.

20. A method according to claim 19, wherein the dynamic mode is drilling with a drill bit or steering the drill bit.

21. A method according to claim 19, further comprising:
   determining a desired vibration level of the drill string by stepping through a series of preprogrammed increments of frequency and pressure amplitude for the pulsing fluid;
   operating the drill string at the desired vibration level;
   monitoring the axial acceleration of the drill string; and
   adjusting the vibration level to improve the axial acceleration of the drill string.

22. A method according to claim 19, wherein the frequency is about 5 to 40 Hz, and pressure amplitude of the valve assembly is controlled by an electronic circuit that monitors real-time pressure and vibration levels down hole.

23. A method according to claim 19, wherein the frequency is adjusted by about 1 Hz when the pressure or vibration level is above or below an acceptable range.