A pumpjack includes a walking beam pivotally connected to a vertical support for oscillation in a generally vertical plane about a first axis. A first end of the walking beam is connected to a sucker rod string. A carriage is movably mounted to the walking beam to move back-and-forth along a length of a tail end of the walking beam. A pitman arm has a first end pivotally connected to the carriage for rotation about a second axis and a second end pivotally connected to a crank arm. A counterweight is mounted to the crank arm and a hydraulic ram is connected to the carriage to move the carriage back-and-forth along the walking beam and establish reciprocation of the sucker rod string.
FIG. 6
FIG. 7
MOBILIZED TAIL BEARING PUMPKJACK

FIELD OF THE INVENTION

[0001] The present invention relates generally to surface equipment for actuating a pump mounted on a bottom end of a sucker rod string for pumping fluid from a well. More particularly, the present invention relates to a modified pumpjack construction that is operated to alternate an amount of counterweight exerted on a tail of a walking beam to maintain a balanced condition on the walking beam throughout an entire pump cycle.

BACKGROUND OF THE INVENTION

[0002] A pumpjack is a type of lever that is widely used to pump fluids from wells. Pumpjacks of numerous constructions have been devised in an attempt to optimize the pumping efficiency and to reduce operating power requirements. Conventionally, a pumpjack includes a lever called a walking beam that is pivotally mounted at its center on a vertical support frame that is often referred to as a Samson post. The pumpjack is powered by a prime mover, such as a combustion engine or electric motor, and operates to convert rotary motion of the prime mover into oscillating motion in the walking beam to reciprocate a rod string and pump lift fluid from a well.

[0003] A pumpjack has many inherent problems. First, the weight exerted on the head end of the walking beam varies during oscillation because the horse head and the counter weight follow an arc and the bridge (connected to the sucker rod string) must lift the weight on a vertical plane created by the movement of the rod string inside the wellbore. With reference to FIG. 1, as the horse head falls below the horizontal it becomes exponentially heavier and as raises above the horizontal it becomes exponentially lighter, which is caused by moving the center of gravity exerted on the walking beam by the horse head and the bridge.

[0004] Second, the pumpjack counter weight is positioned in a fixed location and requires shutting down the pumpjack to reposition the counter weight. Consequently, the counter weight is typically positioned such that the pumpjack operates in an unbalanced condition. The unbalanced condition is related to the continuously varied weight on the head of the pumpjack caused by a myriad of varying wellbore conditions.

[0005] Due to the fact that a pumpjack operates to lift multiple thousands of pounds, these incremental out of balances create sizable increases in operating horsepower requirements. In practice, a pumpjack always operates in out of balance conditions and be must be over powered to overcome them. These out of balance conditions greatly decrease operating efficiency and increase operating costs, as well as, create undue stress on all the components which leads to premature failures of the pumpjack. Conversely, when operated in a balanced condition the horsepower requirements are in the range of 0.01 horsepower per 1000 lbs of weight being lifted and the stresses on the pumpjack are reduced exponentially, as are the operating costs.

SUMMARY OF THE INVENTION

[0006] In one aspect, the present invention provides a modification to a conventional pumpjack that overcomes the problems discussed above and other inherent problems. In an embodiment, the modification includes a mobilized tail bearing that is actuated by a hydraulic or electric ram to vary the distance from the fulcrum at which the counterweight acts on the walking beam. Varying this distance provides the ability to operate the pumpjack in a balanced condition at all times within a wide range of weight drift. It also provides for maintaining a balanced condition throughout the entire reciprocating cycle when utilizing an existing prime mover and gearbox, thereby eliminating the inherent sine wave of unbalanced force that is created by the swinging of the walking beam in an arc and the vertical movement of the rod string.

[0007] In another aspect, the present invention provides a new conventional-style pumpjack with a mobilized tail bearing actuated by a hydraulic or electric ram which can initiate the rotary motion of the counterweight and the reciprocating motion of the walking beam utilizing gravity without the need for a gearbox or prime mover. The process of initiating motion from a balanced condition is easily achieved by over or under balancing the unit making it either head heavy or tail heavy and allowing gravity to act on the unit and overcome friction to initiate motion.

[0008] And the inherent sine wave of unbalanced force that is created by the swinging of the walking beam in an arc and the vertical movement of the rod string is regenerated back into the cycle of positioning and re-positioning the tail bearing.

[0009] In another aspect, the present invention includes a control system that continually monitors sucker rod weight, thereby revealing operating conditions related to the wellbore and the pumping equipment thereby providing invaluable information to the operator.

[0010] In another aspect, the present invention, when embodied as a gravity actuated pumpjack, uses simple equipment and reduces overall complexity of a conventional pumpjack that is equipped with a gearbox and prime mover. The rate of cycling can be accelerated or slowed based on fluid production, thereby continually optimizing daily production rates without equipment modifications. This can greatly reduce the number of jack sizes and stroke lengths required at any given maximum production rates to be achieved. As production rates diminish, the cycles per day can be reduced while maintaining the cycle rate of travel at optimal rates in order to maintain pump efficiency.

[0011] Embodiments of the present invention can reduce overall operating costs by as much a 400% and extend equipment life cycles. Greatly extended equipment live cycles and reduced operating costs will lower the economic limits of any given hydrocarbon production allowing for greater ultimate recoveries of a resource at any given sales price level.

[0012] Embodiments of the present invention provide a modified pumpjack construction for producing fluid from a well that is able to maintain a balanced condition between the head and the tail over a specified range of varying weight and friction encountered in the wellbore. Specific range is established by the amount of static weight bolted to the crank arms and the weight mounting position on the crank arms relative to the crank pin, both of which are mechanically adjusted at time of initial install and when an out of range condition is flagged by the control system.

[0013] Embodiments of the present invention provide a modified pumpjack construction for producing fluid from a well that is able to initiate cycling of the pumpjack utilizing the effects of gravity by oscillating from a balanced condition to a head
heavy then tail heavy condition or vice versa. Energy input requirement to initiate motion from a balanced condition is extremely low, on the order of 0.01 hp/ton of weight, greatly reducing operating costs. Acting from a balanced position greatly reduces the stress on all components and reduces maintenance costs and safety issues.

[0014] Embodiments of the present provide a modified pumpjack construction for producing fluid from a well that is able to sense fluid level in the annular space of a wellbore by comparing the position of the tail bearing in a balanced position from one cycle to the next. Fluid above the pump intake will create buoyancy in the tubing string causing the head end of the pumpjack to become lighter. Pumpjack can start, balance, sense fluid level, cycle until buoyancy is eliminated, shutdown. If no fluid level is detected the pumpjack will shutdown after balancing.

[0015] Embodiments of the present provide a modified pumpjack construction for producing fluid from a well that is able to initiate motion from a stop position when crank arms are hanging vertically (tail heavy) and head weight is attempting to pull straight up on the centerline of the crank pin.

[0016] Embodiments of the present provide a modified pumpjack construction for producing fluid from a well that is able to accelerate the cycling of the pumpjack until a “floating rod string” condition is encountered and then slow the cycling to just below this point thus optimizing the maximum pumping capacity at any given stroke length. This greatly improves the range of production capacity of a given jack size greatly reducing the number of jack sizes, stroke lengths and operating speeds required throughout the life-cycle of a wellbore. This action also dramatically improves the efficiency of the downhole insert pump even at very low daily production rates.

[0017] Embodiments of the present provide a modified pumpjack construction for producing fluid from a well that eliminates the need for a gearbox and associated external prime mover, motion is initiated by gravity acting on the walking beam. This greatly reduces the cost and complexity of manufacture and maintenance.

[0018] Embodiments of the present provide a modified pumpjack construction for producing fluid from a well that is able to detect a wide range of equipment failures by sensing friction and weight throughout the entire rotating cycle. Pump failures and efficiency issues, rod string failures, production tubing failures, bearing failures etc. can all be detected and reported to the control system which is compatible with all any new communication systems available now and in the future. Using this physical method of operation and control system in effect can make the pumpjack “Smart”.

[0019] In an embodiment, a pumpjack for producing fluid from a well includes a walking beam pivotally connected to a vertical support for oscillation in a generally vertical plane about a first axis. A first end of the walking beam is connected to a sucker rod string. A carriage is movably mounted to the walking beam to move back-and-forth along a length of a tail end of the walking beam. A pitman arm has a first end pivotal connected to the carriage for rotation about a second axis and a second end pivotally connected to a crank arm. A counterweight is mounted to the crank arm and a hydraulic ram is connected to the carriage to move the carriage back-and-forth along the walking beam and establish reciprocation of the sucker rod string.

[0020] There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows may be better understood and in order that the present contribution to the art may be better appreciated.

[0021] Numerous objects, features and advantages of the present invention will be readily apparent to those of ordinary skill in the art upon a reading of the following detailed description of presently preferred, but nonetheless illustrative, embodiments of the present invention when taken in conjunction with the accompanying drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of descriptions and should not be regarded as limiting.

[0022] As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

[0023] For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be had to the accompanying drawings and descriptive matter in which there are illustrated preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The following drawings illustrate by way of example and are included to provide further understanding of the invention for the purpose of illustrative discussion of the embodiments of the invention. No attempt is made to show structural details of the embodiments in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice. Identical reference numerals do not necessarily indicate an identical structure. Rather, the same reference numeral may be used to indicate a similar feature of a feature with similar functionality. In the drawings:

[0025] FIG. 1 is a diagrammatic illustration of the difference between arc of the beam and arc the bridle of a pumpjack, illustrating areas of inherent imbalance;

[0026] FIG. 2 is a diagrammatic view of a pumpjack constructed in accordance with the principals of an embodiment of the present invention;

[0027] FIG. 3 is a diagrammatic end view of a carriage and walking beam of the pumpjack illustrated in FIG. 2;

[0028] FIG. 4 is an enlarged, diagrammatic partial side view of the carriage and walking beam illustrated in FIG. 3;

[0029] FIG. 5 is an enlarged, diagrammatic partial side view of the walking beam and a saddle bearing spacer of the pumpjack illustrated in FIG. 2;

[0030] FIG. 6 is a block diagram of an exemplary control system of the pumpjack illustrated in FIG. 2, and

[0031] FIG. 7 is a diagram illustrating power regeneration (conservation) operation of a pumpjack in accordance with embodiments of the present invention.
DETAILED DESCRIPTION OF THE INVENTION

[0032] Referring to FIGS. 2 through 5, there is representatively illustrated a pumpjack 10 that is constructed in accordance with the principals of an embodiment of the present invention. The pumpjack 10 includes a walking beam 12 that is pivotally connected to a vertical support 14 by a saddle bearing 16 so that the walking beam is able to oscillate in a generally vertical plane about the saddle bearing’s rotation axis, similar to a conventional pumpjack. A horse head 18 is connected to front end 20 of the walking beam 12. And the horse head 18 is connected to a sucker-rod string 22 in a conventional manner by a bridle 24.

[0033] A carriage 26 is movably mounted to the tail end 28 of the walking beam 12 to move back-and-forth along a length of tail end 28. A tail bearing 30 is mounted to a lower end of the carriage 26 is pivotally connects an end of a pitman arm 32 to the carriage to rotate about the tail bearing’s rotational axis. The opposite end of the pitman arm 32 is pivotally connected to a crank arm 34 and the crank arm is rotatably connected at one end to a vertical support 36. A counterweight 38 is attached to the opposite end of the crank arm 34.

[0034] A hydraulic ram 40 is mounted, for example, to the walking beam 12 and includes an extensible shaft 42 that is connected to the carriage 26.

[0035] As discussed further below, the hydraulic ram 40 operates to move the carriage 26 back-and-forth along the walking beam 12 by extending and retracting the extensible shaft 42. In an embodiment, the carriage 26 is movable equal distances on opposite sides of a centerline 44 that extends substantially vertically from the pivot or bearing connecting the crank arm 34 and vertical support 36. Further, the rotational axis of the tail bearing 30 and the saddle bearing 16 are disposed on a common centerline 46 that extends between the two bearings. In an embodiment, the tail bearing 30 and the saddle bearing 16 are positioned a same distance from the bottom of the walking beam 12. These arrangements, as will become apparent, permit certain operation of the hydraulic pump 10.

[0036] In the illustrated embodiment, the hydraulic ram 40 is mounted to a saddle 50 that is disposed between the saddle bearing 16 and the walking beam 12. Saddle spacer 56 is sized so as to align centerline 46 generally horizontal along the bottom of the walking beam 12. And at initial setup, the walking beam 12 is balanced with the carriage 26 positioned so that the tail bearing 30 is located on the centerline 44 of the crank arm 34.

[0037] Alternatively, the hydraulic ram 40 could be replaced by an electrically power operator to move the saddle bearing along the walking beam in the manner discussed above.

[0038] As best seen in FIGS. 3 and 4, and in an embodiment, the walking beam 12 is an I-beam and the carriage 26 is movably mounted to the bottom flange of the I-beam by a system of rollers. Particularly, the carriage 26 includes two pairs of running wheels 48 and 50, one pair disposed along each side of the carriage and in rolling contact with a top surface of the bottom flange of the walking beam. Additionally, carriage 26 includes two pairs of up-stop wheels 52 and 54, one pair disposed along each side of the carriage and in rolling contact with a bottom surface of the bottom flange of the walking beam 12. The running wheels 48 and 50 bear the weight of the carriage 26 on the walking beam 12 and the up-stop wheels 52 and 54 prevent the carriage from coming up off the walking beam.

[0039] Further illustrated in FIG. 3, carriage limit stops 56 (only one is illustrated, the other is positioned on the opposite side) are mounted to the walking beam 12 to limit the carriages’ forward travel along the walking beam. In an aspect, each limit stop 56 is wedge shaped and taper from narrow to wide in a direction from the tail toward the front of the walking beam and has a positive stop at the wide end. In an over travel condition, the limit stops 56 wedge between the up-stop wheels 52 and 54 and the walking beam 12 to prevent forward movement of the carriage.

[0040] Also illustrated in FIG. 4 is a carriage lock 58 that includes a structure 60 mounted to the walking beam 12, a corresponding structure 62 mounted to the carriage 12, and a pin or bolt 64 that can be inserted through apertures in structures 60 and 62 so as to lock the position of the carriage along the walking beam.

[0041] Referring to FIG. 6, there is diagrammatically illustrated an exemplary control system 66 for operating the hydraulic pump 10. Control system 66 included a programmable logic controller (PLC) 68, a hydraulic ram position sensor 70, a beam position sensor 72, a load sensing proportional valve 74, and a valve actuator 76. The hydraulic ram position sensor 70 is operatively connected to the hydraulic ram 40 and outputs a signal that is indicative of the position of the ram’s extensible shaft 42. The beam position sensor 72 is operatively connected to the walking beam 12 and outputs a signal that is indicative of the position of the walking beam. The load sensing proportional valve 74 operates to determine the load on the hydraulic ram and output a signal that is indicative of this sense load. The load sensing proportional valve 74 is also hydraulically connected to the hydraulic ram 40 and is operated by valve actuator 76 to control the hydraulic ram.

[0042] The PLC 68 is electrically connected to the hydraulic ram position sensor 70, the beam position sensor 72, the load sensing proportional valve 74, and the valve actuator 76. The PLC operates the valve actuator 76 as a function of the signals received by the hydraulic ram position sensor 70, the beam position sensor 72, and the load sensing proportional valve 74 to move the carriage 26 back-and-forth along the walking beam to drive the pump and reciprocate the sucker rod string.

[0043] Generally, reciprocation of the sucker rod string is accomplished using gravity by alternating the balance of the walking beam 12 between a tail heavy condition and a head heavy condition by moving the carriage 26 back-and-forth along the walking beam 12, which positions counterweight 38 to create either the tail heavy or head heavy condition.

[0044] With reference to FIG. 7, the pumpjack 10 is able to regenerate power throughout rotation of the counter weight crank arms, which is illustrated in four separate quadrants of rotation. Starting with quadrant one, the head is down and the pumpjack is head heavy. The carriage moves rearward causing the pumpjack to be tail heavy and to start lifting the head to horizontal (9:00 position). The bridle moves back to arc of head as the crank approaches horizontal (9:00 position), thereby making the pumpjack head light.

[0045] Continuing in quadrant two, the head is horizontal and weight on the bridle is following arc of the head, the
head becomes lighter as the crank arms fall vertical (6:00 position). The carrier moves forward to shift from tail heavy to head heavy.

[0046] Continuing in quadrant three, the head is upward carrier moves forward to locate balance point (3:00 position) with the beam on the horizontal plane.

[0047] In quadrant four, the head falls below the horizontal, the bridle swings away from the beam, the head increasingly becomes heavy, and the crank arms accelerate (between 3:00 and 12:00 position). The carrier moves rearwardly to shift from head heavy to tail heavy.

[0048] Input energy required in quadrant three and one to move the carrier, crank arms accelerating in quadrant two. Inertia generated in quadrant two is conserved in quadrant three, so the more inertia gained in quadrant two (speed of rotation-unbalance), the deeper into quadrant three the crank arms will rotate. Therefore, less work is required in quadrant three to move the carrier to the balance point. Energy caused by unbalance in quadrant two is regenerated (conserved) into quadrant three. The same principal occurs between quadrants one and four. Further, inherent unbalance caused by the bridle arc is regenerated into input side of energy requirement.

[0049] The PLC 68 can be programmed to perform many different operations, several operations are discussed below.


[0051] In this mode, the PLC 68 operates the hydraulic ram 40 to move the carriage 26 to the most rearward position, e.g., by fully extending the hydraulic ram so the pumpjack is maximum tail heavy and crank arm 34 is disposed at the 6 o’clock position. Indication is given to the operator to install carriage lockout pin and positive lock the crank arms. ESD the hydraulic supply. Await operator reset commands.

[0052] 2. Travel to Park Position.

[0053] In this mode, the PLC 68 operates the hydraulic ram 40 to move the carriage 26 forwardly along the walking beam toward the saddle bearing 16 until the crank arm 34 moves counter-clockwise to the 1 o’clock position. In this position, the walking beam 12 is head down and the pitman arm 32 is parallel to the crank arm 34. The pumpjack 10 is placed in this position when it shutdown to protect the sucker-rod string and polish rod inside the wellbore. Further, operation of the pumpjack 10 is most easily started from this position.


[0055] In this mode, and from the park position, the PLC 68 operates the hydraulic ram 40 to move the carriage 26 is rearward along the walking beam 12 until the crank arm 34 rotates in a clockwise direction and stabilize in the 3 o’clock position. (When the unit is first installed the physical weights are adjusted on the crank arms so that the full string weight and a full column of fluid with no fluid below the pump are balanced with the centerline of the tail bearing carrier on the centerline of the crankshaft).


[0057] In this mode, the PLC 68 operates to determine if the balance point determined in #3 above is forward of the crankshaft centerline it indicates that fluid has entered the wellbore in the annular space outside the production tubing. This will create buoyancy in the tubing string and make the pumpjack lighter at the head end. If no fluid is detected the pumpjack will shut down and go back to the park position #2 above.

[0058] 5. Swab Well.

[0059] In this mode, the PLC 68 is operates the hydraulic ram 40 to alternate moving the carriage 26 forward and rearward causing the pumpjack 10 to oscillate at a set speed. The pumpjack 10 can run in this configuration until the balance point has moved back to the centerline of the crankshaft (indicating a pumped off condition), at which time, the PLC will operating the park position mode. On a gas well that makes water, the jack can be instructed to swab by the external gas flow chart differential as well.

[0060] 6. Produce Well at Maximum Production Rate.

[0061] In this mode, the PLC 68 operates the hydraulic ram 40 to move the carriage 26 back-and-forth along the walking beam 12 to accelerate rotation of the walking beam until the sucker-rod string starts to float (hydraulic ram will see the floating if the rate begins to exceed buoyancy or friction factors present in the well). This is the maximum production rate possible with the least amount of energy expended. If the pumpjack 10 cannot attain this condition then the PLC instructions the operator to lengthen the stroke or in an extreme case require the well to be equipped with a bigger jack. This feature will allow the manufacture of the pumpjacks to reduce the number of jack sizes offered as the production rates attainable with any given stroke length can be optimized. The PLC is capable of learning to slow down pumping as the well approaches pumped off conditions and speed up to optimize production rates.


[0063] At all times during operation, the PLC 68 can detect wellbore conditions, pump efficiency, holes in production string, leaking travel balls, broken rods, tight packings, etc. by monitoring pressure balances across the hydraulic ram 40. The pumpjack 10, in essence, becomes its own dynamometer. The PLC 68 can easily be tied to SCADA control or even monitored with a mobile computing device.

[0064] A number of embodiments of the present invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

Preliminary Amendment

1. A pumpjack for lifting fluid in a well bore, the pump comprising:

   a walking beam pivotally connected to a vertical support for oscillation in a generally vertical plane about a first axis, a first end of said walking beam connected to a sucker rod string;

   a carriage movably mounted on a bottom of said walking beam for movement back-and-forth below the walking beam along a length of a tail end of said walking beam; a pitman arm having a first end pivotally connected to a bottom of said carriage for rotation about a second axis and a second end pivotally connected to a crank arm; and a counterweight mounted to the crank arm; and a hydraulic ram connected to said carriage beneath the walking beam for moving said carriage back-and-forth along said walking beam and establish reciprocation of the sucker rod string.

2. The pumpjack of claim 1, wherein said first and said second axis is disposed vertically below said walking beam.

3. The pumpjack of claim 3, wherein said first and said second axis are disposed along a common centerline that extends between said first axis and said second axis.
4. The pumpjack of claim 1, wherein said carriage is movable equal distances on opposite sides of a crank arm centerline that extends substantially vertical from a pivot connection between the crank arm and a second vertical support.

5. The pumpjack of claim 1, further comprising:
   one or more carriage stops mounted to said walking beam.

6. The pumpjack of claim 1, further comprising:
   a programmable logic controller,
   a hydraulic arm position sensor operatively connected to said hydraulic ram to determine the position of an extensible shaft of said hydraulic ram and output a hydraulic ram position signal that is indicative of the determined position of the extensible shaft;
   a beam position sensor operatively connected to said walking beam to determine the position of said walking beam and output a beam position signal that is indicative of the determined position of said walking beam;
   a load sensing spool valve operatively connected to said hydraulic ram to determine a load on said hydraulic ram and output a load signal that is indicative of the determined load on said hydraulic ram, said load sensing spool valve hydraulically connected to said hydraulic ram;
   a valve actuator operatively connected to said load sensing spool valve;
   said PLC electrically connected to said hydraulic arm position sensor to receive said hydraulic ram position signal, electrically connected to said beam position sensor to receive said beam position signal, electrically connected to said load sensing spool valve to receive said load signal; and
   said PLC programmed to operate said valve actuator based on said hydraulic ram position signal, said beam position signal, and said load signal to cause said hydraulic ram to move said carriage back-and-forth along said walking beam.

7. The pumpjack of claim 6, wherein said PLC is programmed to perform a maintenance shut down operation.

8. The pumpjack of claim 6, wherein said PLC is programmed to perform a travel to park position operation.

9. The pumpjack of claim 6, wherein said PLC is programmed to perform a balance operation.

10. The pumpjack of claim 6, wherein said PLC is programmed to perform a check for fluid level operation.

11. The pumpjack of claim 6, wherein said PLC is programmed to perform a swab well operation.

12. The pumpjack of claim 6, wherein said PLC is programmed to perform a produce well at maximum production rate operation.

* * * * *