A METHOD AND APPARATUS FOR MONITORING A JACK-UP RIG

The present invention relates to a method and apparatus for monitoring a jack-up rig and for facilitating erection thereof.

There are many types of offshore platforms used mainly in the construction, maintenance and repair of oil and gas wells. Offshore platforms known as "jack-up platforms" are floating vessels with legs driven by jacking units extending down and contacting the sea floor. A "jack-up" platform is any self-elevating offshore platform or deck with one or more legs, each leg consisting of one or more chords, used for any of a variety of operations, including, but not limited to, drilling, production, workover, or other offshore operations or work, which has the ability of being supported on jackable leg(s) to the seafloor, optionally with the capability of relocating from one offshore location to another by lowering to an afloat position, being moved to a new offshore position, and raising itself again to an elevated position. Such "off-shore" rigs and platforms are well-known and typically include a drilling rig or "hull" generally mounted on multiple legs, for example three or more legs, each provided with a base forming a supporting foot ("spud can" of the leg). In certain systems, each has one or more chords structurally connected to each other forming one unit (a "leg"). Legs with one to four chords are now in use. Each chord has one or two (opposite to each other) racks. Each rack is driven by one or more pinions. The rig or platform is positioned at a desired site, and then raised to an operational height above the sea. Motorized displacement ("jacking") of the rig along each of its legs raises the rig. Each leg can be raised

independently of the other legs to a certain extent, so that an operator can, for example, correct uneven penetration of the legs into the sea bed.

The rig is raised or lowered in relation to each leg by sets of racks-and-pinions driving each leg, the systems generally with three legs being arranged in each angle or corner of a triangular structure with three metal chords and struts ("chord" designating each "member" of each leg). The jacking system of this type includes at least one elongated rack which is mounted vertically on the exterior side surface of the upright legs and extends substantially through the entire length of the same, and a plurality of cooperating pinions engaged with each of the racks. Each of pinions is driven through a series of reduction gears by means of a respective motor. When the platform is supported by the upright legs on the sea floor, this support is effected by the engagement of the rack with the pinion of the jacking system. In this manner, during offshore operations the load which is composed of the self-weight of the platform and environmental forces such as wind, wave, current and others is placed on the jacking system in engagement of the rack with the pinion.

When the position of a given leg is changed, the pinions relating to this leg are in operation simultaneously, in the same direction and with the same theoretical speed. The speed of linear displacement depends on the load on the leg. When a leg is inclined, the least-loaded chord is raised more quickly than the others by its motors, resulting in an additional increase in "Rack Path Difference" or rack phase differential (or "RPD") on the leg concerned. The relative position of the rig (hull) and of the legs (geometry of the system)

in relation to the sea bed is, in many prior systems, checked in relation to two series of fixed reference points, which are the bottom of the hull of the rig and the top of the "jacking structure" or "jacking house".

Correct positioning can be inhibited by many factors: for example incorrect positioning by an operator; the existence or appearance of major lateral stresses or loads, such as those due to currents, swell and/or wind; uneven embedding of the feet of the legs; heterogeneous or inclined ground; or to an operating fault on a lifting motor or brake. Often it is difficult to determine which factors are involved. Excessive stresses on the structure and particularly on the legs, with the risk of damage to the legs, can lead to rig down time and a significant reduction of the service life of the rig.

"Rack Path Differential" (difference for a given rack path, i.e. geometrical difference in the structure for a given number of rack notches) is a horizontality defect. Normally, when the rig is on site, the legs are lowered until their tips are resting on the sea bed, then the rig is raised out of the water up to its operating position. This involves a certain penetration of the tips into the sea bed, according to the nature of the bed, but normally the legs remain vertical and the only forces acting on the unit remain within the strength limits selected when designing the rig. However, in certain cases, the sea bed may be inclined or uneven, etc., which can cause a horizontal deviation, a deviation of one or more legs in relation to the vertical, which creates a bending moment on the leg or legs concerned. These deviations, if they affect two or three legs, are not necessarily parallel to each other, which can

complicate the problem. Such bending causes the load to become unequal on the three chords of the leg concerned, the leg being in a skewed position with respect to its guide. The imbalance can be such that it is no longer possible to move the rig. The rig then has to be lowered again to water level, to a floating state to eliminate the load, the supporting legs are withdrawn from the sea bed over a part of the penetration obtained, and then the jacking operation is recommenced. This may possibly be combined, according to the seriousness of the situation, with a slight shift of position in order to avoid the first footprints, although such an operation is not generally recommended, and with a backward and forward movement of the legs such as reaming to correct the deviation. Such action is obviously time consuming and is not always successful. In certain severe situations, a decision has to be made to move the rig from the planned drilling point to another location 50 to 100 meters away, and to recommence the operation, with the same uncertainties. This latter solution is impossible to implement when the rig has to be located alongside a fixed production platform. In such a case, only a margin of a small distance is available for jacking up the rig.

There has long been a need, recognized by the present inventors, for effective and efficient systems and methods for both monitoring loads on rig legs and for monitoring changes in position of the legs.

In accordance with a first aspect of the present invention, there is provided a method for monitoring a jack-up rig comprising a platform, at least one leg, at least one chord having a toothed rack and a jacking apparatus comprising a climb pinion apparatus driven by a motor for jacking the platform on the at least one leg, the climb pinion

apparatus comprising a gear for meshing with the toothed track and a shaft, wherein at least one strain sensing apparatus is provided on the climb pinion apparatus, the method comprises the steps of obtaining a signal indicative of strain with the strain sensing apparatus and a signal indicative of a load on said motor, sending said signals to a control system, and processing said signals to produce a value of a load on the chord.

Preferably, the strain sensing apparatus is located on the shaft, the method comprising the step of using the strain sensing apparatus to sense strain in the gear to produce the signal indicative of strain. Advantageously, the strain sensing apparatus is located on the shaft, the method comprising the step of using the strain sensing apparatus to sense strain in the shaft to produce the signal indicative of strain

Advantageously, the climb pinion apparatus further comprising at least one further gear and a further shaft wherein the at least one strain sensing apparatus is arranged on the further shaft, the method comprising the step of using the strain sensing apparatus to sense strain in the further pinion to produce the signal indicative of strain. Preferably, the climb pinion apparatus further comprising at least one further gear and a further shaft wherein the at least one strain sensing apparatus is arranged on the further gear, the method comprising the step of using the strain sensing apparatus to sense strain in the further gear to produce the signal indicative of strain. Advantageously, the strain sensing apparatus is located on the gear, the method comprising the step of using the strain sensing apparatus to sense strain in the gear to produce the signal indicative of strain.

Advantageously, the at least one strain sensing apparatus is a plurality of strain gauges. Preferably, the plurality of strain gauges are placed on the shaft and the further shaft to sense strain in the shaft and further shaft to produce the signal indicative of strain. Advantageously, the plurality of strain gauges are placed on the gear and the further gear to sense strain in the gear and further gear to produce the signal indicative of strain. Preferably, there are a plurality of shaft and gears, at least several of which are provided with strain gauges to sense strain in the at least several of the plurality of shaft and gears to produce the signal indicative of strain.

Preferably, the method further comprises the step of displaying on a display a load measurement for the chord. Preferably, the load measurement is displayed on the display in real time.

Advantageously, the at least one strain sensing apparatus forms part of a load monitor. Advantageously, load on the motor is measured and a signal indicative of the load on the motor is sent to the control system.

Preferably, the method further comprises the step of comparing the value of a load on the chord with a specified value and if the value of a load on the chord is greater than the specified value, activating an alarm. The specified value may be an absolute predetermined value, or may be obtained from historical values, or may be relative and vary according to loads on other legs. Preferably, the alarm is either a visual alarm and/or a sound alarm.

Advantageously, the method further comprises the step of maintaining a historical record of value of a load on the chord and accessing the historical record

using the control system.

Preferably, the method further comprises the step of measuring rotation of the gear with rotation measuring apparatus to obtain a displacement signal indicative of linear displacement of the platform relative to the leg and sending the displacement signal to the control system and processing the displacement signal to produce a value of a linear displacement of the platform relative to the leg. Advantageously, the jacking apparatus is suspended in or on a resilient member on the platform the method further comprising the step of measuring vertical displacement of each jacking apparatus in relation to the platform using a distance measuring device.

Advantageously, the method further comprises at least a second leg, at least one second chord having a second toothed rack and a second jacking apparatus comprising a second climb pinion apparatus driven by a second motor for jacking the platform on the second leg, the second climb pinion apparatus comprising a second gear for meshing with the second toothed track and a second shaft, characterised in that at least a second strain sensing apparatus is provided on the second climb pinion apparatus the method comprising the steps of obtaining a second signal indicative of strain with the strain sensing apparatus and sending the second signal to a control system and processing the second signal to produce a value of a load on the second chord.

Preferably, the method further comprises the step of providing a rack path differential monitoring system for monitoring rotation of each pinion to provide an indication of a linear displacement of each selected pinion of each chord and the leg associated therewith for comparison to indicate rack path differential for the

legs of the platform. Preferably, the result will identify possible twisting of each leg. Advantageously, the displacement is displayed on a display in real time. Preferably, a second historical record of the displacements in kept and accessed from the control system.

In accordance with a second aspect of the present invention, there is provided an apparatus for monitoring a jack-up rig comprising a platform at least one leg, at least one chord having a toothed rack and a jacking apparatus comprising a climb pinion apparatus driven by a motor for jacking the platform on the at least one leg, the climb pinion apparatus comprising a gear for meshing with the toothed track and a shaft, wherein at least one strain sensing apparatus is provided on the climb pinion apparatus for obtaining a signal indicative of strain with the strain sensing apparatus and sending the signal to a control system, the apparatus further comprises a load measuring apparatus for measuring a load on the motor to produce a motor load signal indicative of the load on the motor and sending the motor load signal to the control system, and the control system is configured for processing said signals to produce a value of a load on the chord.

Preferably, the apparatus also comprises rotation measuring apparatus for measuring linear displacement of the platform relative to the leg. Preferably, the apparatus further comprises a distance measuring device for measuring vertical displacement of each

jacking apparatus in relation to the platform.

In accordance with a third aspect of the present invention, there is provided a system for monitoring a jack-up rig comprising a platform, at least one leg, at least one chord having a toothed rack and a jacking apparatus comprising a climb pinion apparatus driven by a motor for jacking the platform on the at least one leg, the climb pinion apparatus comprising a gear for meshing with the toothed track and a shaft, wherein at least one strain sensing apparatus is provided on said climb pinion apparatus for obtaining a signal indicative of strain with said strain sensing apparatus and sending said signal to a control system, the system further comprises a load measuring apparatus for measuring a load on the motor to produce a motor load signal indicative of the load on the motor and sending the motor load signal to the control system, and the control system is configured for processing said signals to produce a value of a load on said chord.

The present invention, in at least certain aspects, discloses systems and methods for simultaneously monitoring the rack path differential of chords of a platform's legs and for monitoring the load on each of

the legs. In certain aspects, sudden changes in leg position are detected.

In certain aspects, the present invention discloses a load monitoring system and a rack path differential monitoring system for jacking systems for, including floating jacking systems.

In certain particular aspects the present invention discloses a leg load monitoring system in which a shaft of a rack and pinion gear system has one or more strain sensors thereon, information from which is transmitted to a control system (for example any suitable computer system or programmable logic controller or "PLC").

In certain aspects, the present invention discloses load monitoring systems ("PLMS" means pinion load monitoring system) and rack path differential reading apparatus for jacking systems of the rack and pinion type. A pinion shaft, within a gear train, is provided with strain sensing components and a series of sensors are provided to measure the rotational amount and directional displacement of the same or another shaft arrangement. The information gathered from the strain measurements of a shaft, while static or in motion, is transmitted to a static connection in a junction box by means of a slip ring while the rotational measurement, being received on a static connection, is also directed to a junction box. All the information collected is fed into a computer (for example a PLC), optionally with displays located in or near the jacking system console. variations in the readings greater than specified, trigger a visual and/or sound alarm, requiring attention of the operator to effect corrections to the loadings and/or positioning of individual drives or a jack unit.

In certain particular aspects, in the case of

"floating jacking systems," certain systems in accordance with the present invention include an additional measurement of the vertical displacement of the jack unit in relation to the platform accomplished by means of a distance measurement device (see, for example, devices D, Figure 10). The information collected from this measurement is combined with the information from the rotational readings and fed into a computer and processed.

The present invention, in certain aspects, discloses a rack path differential monitoring system which includes the detection of the relative position of each chord with respect to the deck of the platform for identifying possible twisting or skewing of the legs due to imbalanced loading or effects due to the conditions of the seafloor as mentioned above, and/or uneven displacement of the chords and/or legs with respect to the deck.

The present invention discloses, in certain aspects, methods for monitoring a load on a chord of a leg of an oilfield platform, the chord with a corresponding toothed rack, a rack-and-pinion leg jacking system for jacking the leg up or down, the rack-and-pinion leg jacking system with a motor, gear system with pinions, and a climbing pinion for meshing with the leg's toothed rack, the method including: providing for the selected chord at least one strain sensing apparatus on a selected pinion of the rack-and-pinion system associated with the selected chord; with the at least one strain sensing apparatus, sensing strain on the selected pinion, said strain indicative of load on the selected chord and on the selected chord's associated leg, and producing a signal indicative thereof; and transmitting said signal

to a control system, and processing said signal producing a value of a load on the selected chord.

The present invention discloses, in certain aspects, a method for monitoring load on legs of an oilfield platform, and, therefore, total platform load, the platform having a plurality of legs, each leg with a plurality of chords, each chord with a corresponding toothed rack, a rack-and-pinion leg jacking system for each chord for jacking the legs up and down, each rack-and-pinion leg jacking system with at least one drive unit, each of the at least one drive unit having a motor, a gear system with pinions, and a climbing pinion for meshing with a corresponding toothed rack, the method including: providing a load monitor of each chord with at least one strain sensing apparatus on a selected pinion of a rack-and-pinion system leg jacking system of each chord, including a selected pinion for each of the at least one drive unit of each rack-and-pinion leg jacking system; with each said load monitor's at least one strain sensing apparatus, sensing strain on all the selected pinions, said strains indicative of load on the associated chord, and producing a signal indicative thereof for each chord of the leg, the signals including signals for each drive unit; transmitting said signals to a control system, and processing said signals producing a value of load on each leg, summing load on each leg providing load on the platform; within the control system, comparing the value of leg loads to a specified leg load values, and/or the total platform load to a specified value for total platform load; if any specified value is exceeded, producing an alarm for a system operator.

The present invention discloses, in certain aspects,

system for monitoring load on a chord of a leg of an oilfield platform, the system including: a load monitor for each drive unit of the chord, with at least one strain sensing apparatus on a selected pinion of each drive unit for sensing strain on the selected pinion, said strain indicative of a load on the associated chord and producing signals indicative thereof; a control system; transmission apparatus for transmitting said signal to the control system; and the control system for processing said signals to produce a value of load on said chord.

The present invention discloses, in certain aspects, system for monitoring legs of an oilfield platform, the platform having a plurality of legs, each leg with a plurality of chords, each chord with a corresponding toothed rack, a rack-and-pinion leg jacking system for each chord for jacking the legs up and down, each rack-and-pinion leg jacking system with a plurality of drive units, each drive unit with a motor, gear system with pinions, and a climbing pinion for meshing with a toothed rack of a chord, the system including: a load monitor of each drive unit with at least one strain sensing apparatus on a selected pinion of the drive unit for sensing strain on the selected pinion, said strain indicative of load on the associated chord and producing signals indicative thereof; a control system; transmission apparatus for transmitting said signals to the control system; the control system for processing said signals to produce a value of leg load on each leg and platform load on the platform; and said control system for comparing said values to specified values for leg load and for platform load, and if said specified value is exceeded for either leg load or for platform

load, the control system for producing an alarm for a system operator.

Such systems and methods can simultaneously provide monitoring of both leg rack path differential and leg loading.

For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is a side schematic view of a rig apparatus in accordance with the present invention;

Figure 2 is a top schematic view of the rig apparatus shown in Figure 1;

Figure 3 is a side view of part of the rig apparatus shown in Figure 1;

Figure 4 is a perspective view of part of a rig leg and jacking unit in accordance with the present invention;

Figure 5 is a view of part of a gear train of the jacking unit shown in Figure 4;

Figure 6 is a schematic view of part of the jacking unit shown in Figure 4;

Figure 6A is a perspective view of part of the jacking unit shown in Figure 6 in a housing;

Figure 6B is an enlarged view of part of the jacking unit and housing shown in Figure 6A;

Figure 6C is a perspective view of part of the jacking unit shown in Figure 6;

Figure 6D is a perspective view of part of the jacking unit shown in Figure 6;

Figure 7 is a schematic view of a system in accordance with the present invention;

Figure 8 is a schematic view of part of an apparatus in accordance with the present invention;

Figure 9 is a schematic view of part of an apparatus in accordance with the present invention; and

Figure 10 is a schematic view of a system in accordance with the present invention.

Figures 1 and 2 show a jack-up rig 10 in accordance

with the present invention which includes a barge type hull 12 having three legs, each identified by the reference numeral 14, which each movably extend through the hull 12 within a spud well 16 with at least one set of rack teeth 18 attached to each of the legs 14. The hull 12 supports the legs 14 in an upright position. When the rig 10 arrives at its intended location, the legs 14 are lowered down until firmly engaged with the ocean floor. Continued jacking on the legs 14 lifts the hull 12 to a nominal height above the body of water 13 for preload operations. Upon the completion of preloading, jacking resumes until the bottom of the hull 12 reaches an elevation above the sea, for example greater than the highest wave height anticipated during a severe ocean storm. The main deck of the hull 12 may be outfitted with the necessary equipment to conduct operations, for example drilling, production or workover operations, such as a derrick 20, a cantilever beam and elevated pipe rack 22, pilot house 27, heliport 28, crew quarters 29, as well as general purpose cranes 30.

Elevation of the hull 12 of the jack-up rig 10 is achieved by a number of different techniques which are well known to the industry. One form of elevation system in accordance with the present invention is useful with a rack and pinion elevating system in accordance with the present invention. Elevating pinions 32 are housed in a jacking frame 34, on and within which is drive apparatus (electric or hydraulic) with a drive mechanism and a gear train to drive the elevating pinions 32. The elevating pinions 32 engage the rack teeth 18 on a leg chord 36. Rotation of the pinions 32 in one direction moves the legs 14 upwardly relative to the hull 12, while rotation of the pinions 32 in the opposite direction lowers the

legs 14 relative to the hull 12. An upper guide structure 38 is mounted above the jacking frame 34 and is used as an upper guide/support structure to control the position of the legs 14. The upper guide structure 38 is laterally supported back to the hull or deck 12 with brace beams 39. Each of the legs 14 has one or more generally vertically extending leg chords 36 which are structurally tied together by suitable bracing. For the embodiment shown, rack teeth 18 are provided on both sides of four chords of each leg 14. For smaller platforms, the leg members may consist of a single leg or leg chord with one or more tooth rack 18 thereon. Locking apparatuses 40 selectively lock the legs in position.

One pinion in the system, for example a drive pinion 32, has at least one (one shown) strain gauge 50 thereon for measuring load on the pinions 32 under static or dynamic conditions. The strain on a pinion shaft which is indicative of load jacking unit which is indicative of load on the corresponding leg which is indicative of load on the platform. A control system 54 which includes a control system 54a for each leg is in communication with each strain gauge 50, in one aspect via a slip ring assembly. The strain gauge(s) may be directly connected to the systems 54a with the systems including the devices etc. for communication with the strain gauge(s); optimally, each strain gauge can be connected to a junction box 58 which is in communication with the systems 54a. The control system 54 is also in communication with a jacking system console 56 with display 59 showing the load (in one aspect, in real time) on each pinion, for example a drive pinion 32.

Figure 4 shows an enlarged view of part of a rig in

accordance with the present invention which includes a leg 102 (shown partially; for example like the legs 14, Figure 1) with chords 104 each with a corresponding toothed rack 106. A jacking unit 100 (one for each chord) has spaced apart climbing pinions 108 which mesh with a rack 106. Motors 120, via couplings 121, turn pinions 122 which turn additional mechanism (gears, pinions, etc; not shown in Figure 4) in a gear train 124. Brakes 126 provide selective braking for the motors 120. Each pinion 122 has at least one strain gauge 130 thereon (like the strain gauges 50, Figure 3) which is in communication with suitable junction box(es) and/or control system(s). (Two, three, four or more strain gauges may be used as is true for any pinion or shaft of any embodiment in accordance with the present invention.)

Figure 5 shows an exploded view of some parts of one embodiment of a jacking unit 100 and of a gear train 124. The motor 120 drives the pinion 122 whose gear 122a on a shaft 122s meshes with a gear of an adjacent pinion assembly 132, and so on for additional pinion assemblies 133, 134 and 135 each with corresponding gears.

Each pinion assembly 132 to 135 has gears for meshing with adjacent assemblies and a shaft (132s 135s, respectively) on which the gears are mounted. Any and all shafts of any and all pinion assemblies may have one, two, three, four or more strain gauges thereon (like the strain gauges 50 or 130) in communication with a suitable junction box and/or control system. As an example, and not by way of limitation, a strain gauge 134g is shown on the shaft 134s and strain gauges 135g are shown on the shaft 135s. It is within the scope of the present invention to use any suitable motor and any suitable gear train to drive the climbing pinions 108.

The gears and shafts of the gear train are under load unless the rig or platform has separate structures for holding the legs fixed in position.

Figure 6 shows schematically parts of the apparatus shown in Figures 4 and 5. The strain gauges 130 are connected to a slip ring 142 sending the signal to signal conditioner/transmitters 145 within a junction box 144 (see Figure 6A). The signal transmitters 145 convert the signal coming from the slip ring 142 into an output that travels through the junction box 58 to a programmable logic controller ("PLC") the output of which may include numerical, graphical and/or alarm signals that may be directed to display devices on the rig and/or to a main console of the platform. A system (for example the system 150 with one or more programmable logic controllers 154) receives signals from the signal conditioner/transmitters 145 which receive signals from the strain gauges 130 (in one aspect, sixteen strain gauges are used spaced apart around the shaft). A rotation sensor apparatus (for example 140 or 210, Figure 8) detects marks, ridges, or indentations 141 on the shaft providing an indication of rotation direction and the number of rotations of the shaft 122s. This rotation, being part of the gear train, is directly proportional to the rotation on the pinion 108 (see Figure 5) which translates into the linear displacement of the rack 106 with respect to the platform 12 (Figure 1) and, therefore, the signal, translated into a linear dimension, is sent to the display 152 (or display 59, Figure 3) as is compared against other similar readings from the other jack units on the rig, which may give indication of any rack path differential among all chords on the rig. The slip ring assembly 142 sends signals,

via the junction box 144, to the control system 150. Results based on strain gauge output and/or rotation sensor output are displayed on an optional display 152.

A jacking unit 100 can move slightly with respect to its corresponding rack (and leg), both up and down and at an angle away from horizontal (for example two degrees). In one aspect, the jacking units 100 are mounted between shock pads 162 and 164 in a housing or frame 161 to provide a small "float" distance between the jacking units and the rig deck 170. To measure this movement (the float distances), one, two, or more position transducer assemblies 165 (which can measure the distance between two points) are placed between the deck 170 and the jack unit 100. The assembly 165 has, in one aspect, a spring loaded, cable-actuated, digital, displacement transducer that is attached to the deck or the jack unit while the cable end is attached to the opposite part (the deck 170 or the jack unit 100); and as the cable 166 attached at point 163 is pulled out or retrieved into the transducer (see Figure 6B), the distance is measured and a signal representative of the measurement is transmitted combined with that of the rotation sensor apparatus 140, described above, resulting in the measurement of the actual displacement between the platform and the leg chords. Cables 166 are connected to position transducer assemblies 167 which provides signals indicative of jacking unit position (and, therefore, over time of any jacking unit movement), to the control system (for example system 150 or 54) either directly or via a junction box. The position transducer assemblies 167 have an input/output connection 169 (for example for cables 303, see Figure 10). The amount of extension of a cable 166 indicates the relative position of the jacking

unit with respect to the frame 161.

Figure 7 illustrates schematically a monitoring system 171 in accordance with the present invention for monitoring loads on pinion shafts of a gear train of a jacking unit of a rig and for monitoring rack path differential in accordance with the present invention. Since the load (strain) on the platform, its legs, and the legs' jacking units is transferred to the jacking unit's gear train (the pinions of the gear train are always under the load), measuring the load on a shaft of a pinion of the gear train provides an indication of the load on the legs and on the platform. The strain gauges on a pinion shaft provide a signal indicative of load in both static and dynamic conditions. The signals from the strain gauges, transmitted to the control system, can, after processing by the control system, result in a warning or an alarm.

As shown in Figure 7, for the load monitoring function 172, each jacking unit J for chords C has a corresponding junction box JB in communication with a corresponding programmable logic controller (PLC) 172 (or multiple PLC's are used). Three jacking units J are shown for a three chord leg. (There are, for example, four units per leg in other systems in accordance with the present invention.) Since the driving pinions of the gear train are always engaged with corresponding racks, displacement (movement) of the racks, and therefore of the legs, can be detected by monitoring rotation of a pinion shaft of the gear train. The amount of rotation, and its direction, can be measured by using a system 174 with a set 178 of proximity sensors adjacent a shaft for detecting ridges and/or depressions on the rotating shaft (or placed near the gears' teeth, and protected from oil

or other lubricants). Each system 178 is in communication with a programmable logic controller 177 via a junction box JX. Numeral 171, Figure 7, indicates the load monitoring system.

A real time display of load measurements and leg displacement measurements is provided on a display 184. By maintaining in the PLC's, or in other storage devices, or in a control system 180 with a jacking system console 181, a log of the measurements over time, previous measurements can be accessed and displayed. Warnings and/or alarms are provided via alarm apparatus 182 (for example audio, visual or both).

Figures 8 and 9 illustrate schematically different methods and structures in accordance with the present invention for measuring strain on a rotating shaft and for measuring rotation of the shaft. As shown in Figure 8 a shaft 200 (for example any shaft of a jacking unit's gear train) has two spaced apart gears 201, 202 secured thereto. Strain gauges 204 are spaced apart around the entire circumference of the shaft 200 between the gears 201, 202 (in an area which is a torque affected area, i.e. an area in which the torque produces a twisting on the shaft and the resulting strain is read by the strain gauges 204). Wires 206 from the strain gauges 204 are secured to the exterior of the shaft 200 (for example with an adhesive, for example epoxy) and are connected to an input of a slip ring 214 and then to output wires 208 which are then connected to a junction box (or boxes), not shown (for example like that of Figure 3). A rotation sensor device 210 senses notches 212 in the shaft 200 (or, optionally, senses the spacing of gear teeth of any gear on the shaft) and transmits signals indicative of shaft rotation based on such sensing via a

wire 209 to a signal transducer 213 in a junction box. The wires connected to the slip ring connect the slip ring 214 to a control system (for example via a junction box). Optionally, notches, indentations, depressions or ridges on a gear are sensed by the rotation sensor. A holding bracket 222 holds the slip ring in place.

As shown in Figure 9 a shaft 250 of a motor M (like the motor 120, Figure 4) has a gear 252 secured thereto with a series of spaced apart strain gauges 254 around the shaft 250. Wires 256 from the strain gauges 254 go through holes 258 to a slip ring 260. Notches 262 on the shaft 250 are sensed by a rotation sensor device 264. Output wires from the rotation sensor device 264 are connected to a junction box 270 which is in communication with a control system S (any described herein). A holding bracket 274 holds a static end of the slip ring 260 in place. The torque affected area for the shaft 250 is the area between a coupling 251 and the gear 252. The motor M has a brake B (like the brake 126, Figure 4).

Figure 10 shows a system 300 in accordance with the present invention for a leg A of a platform that has three legs, Legs A, B, C. The system 300 includes parts, devices and components identified with numerals indicating the same parts, etc. described above and identified with these same numerals. Legs B and C each have a system like the system 300 - system 302 (Leg B) and system 304 (Leg C).

The present invention, therefore, provides in at least certain embodiments, a method for monitoring legs of an oilfield platform, the platform having a plurality of legs, each leg with a plurality of chords, each chord with a corresponding rack, the platform including a rack-

and-pinion leg jacking system with a motor and gear system with pinions for each leg for jacking the legs up, the method including providing a load monitor of each leg with a strain sensing apparatus on a selected pinion of the rack-and-pinion system, said selected pinion associated with a particular leg of the platform, and providing a rack path differential monitoring system for monitoring rotation of each selected pinion to provide an indication of a linear displacement of the selected pinions and the legs associated therewith for comparison to indicate rack path differential for racks of the legs of the platform.

The present invention discloses in some, but not necessarily all, embodiments a method for monitoring a load on a chord of a leg of an oilfield platform, the leg with a plurality of chords, each chord with a corresponding toothed rack, each leg having a rack-and-pinion leg jacking system for jacking the leg up or down, each rack-and-pinion leg jacking system with a motor, gear system with pinions, and a climbing pinion for meshing with a leg's toothed rack, the method including: providing for a selected chord at least one strain sensing apparatus on a selected pinion of the rack-and-pinion system associated with the selected chord; with the at least one strain sensing apparatus, sensing strain on the selected pinion, said strain indicative of load on the selected chord and on the selected chord's associated leg, and producing a signal indicative thereof; and transmitting said signal to a control system, and processing said signal producing a value of a load on the selected chord. Such a method may have one or some of the following in any possible combination: wherein the at least one strain sensing apparatus is a plurality of

strain gauges; measuring load on multiple pinions of the rack-and-pinion leg jacking system; displaying on a display a load measurement for the selected chord; wherein load measurement is displayed in real time.

The present invention discloses in some, but not necessarily all, embodiments a method for monitoring load on legs of an oilfield platform, the platform having a plurality of legs, each leg with a plurality of chords, each chord with a corresponding toothed rack, a rack-and-pinion leg jacking system for each chord for jacking the legs up and down, each rack-and-pinion leg jacking system with at least one drive unit, each of the at least one drive unit having a motor, gear system with pinions, and a climbing pinion for meshing with a corresponding toothed rack, the method including: providing a load monitor of each chord with at least one strain sensing apparatus on a selected pinion of a rack-and-pinion system leg jacking system of each chord, including a selected pinion for each of the at least one drive unit of each rack-and-pinion leg jacking system; with each said load monitor's at least one strain sensing apparatus, sensing strain on all the selected pinions, said strains indicative of load on the associated chord, and producing a signal indicative thereof for each chord of the leg; transmitting said signals to a control system, and processing said signals producing a value of load on each leg; within the control system, comparing said value to a specified value; and if said specified value is exceeded, producing an alarm for a system operator; wherein the at least one strain sensing apparatus is a plurality of strain gauges; wherein the alarm is one of visual alarm and sound alarm; displaying on a display load measurements for each drive and/or for

each leg; wherein load measurements for each leg are displayed in real time; maintaining an historical record of load measurements for each leg; and with the control system, providing access to the historical load measurements; wherein the control system includes, for each leg, a programmable logic controller for processing signals indicative of load; each programmable logic controller of a particular leg in wired communication with the at least one strain sensing apparatus of each chord of said leg, processing the signals indicative of load with the programmable logic controllers; maintaining an historical record of all signals and/or load measurements for each chord and/or leg; and with the control system, providing access to the historical load measurements; measuring vertical displacement of each leg jacking system in relation to the oilfield platform using a distance measuring device; providing a rack path differential monitoring system for monitoring rotation of each selected pinion to provide an indication of a linear displacement of each selected pinion of each chord and the leg associated therewith for comparison to indicate rack path differential for the legs of the platform; wherein the oilfield platform has a deck, the method further including detecting relative position of each chord with respect to the deck to thereby identify possible twisting of each leg; wherein each rack has associated therewith a measurement apparatus for measuring actual displacement between each chord and the platform, the method further including providing a signal from each measurement apparatus to an associated programmable logic controller of the control system for determining the displacement between each chord and the platform; providing a display in real time of

displacement between each chord and the platform; maintaining in the control system a second historical record of said displacements; and/or with the control system, providing access to the second historical record.

The present invention discloses in some, but not necessarily all, embodiments a method for monitoring load on legs of an oilfield platform, the platform having a plurality of legs, each leg with a plurality of chords, each chord with a corresponding toothed rack, a rack-and-pinion leg jacking system for each chord jacking the legs up and down, each rack-and-pinion leg jacking system a plurality of drive units, each drive unit with a motor, gear system with pinions, and a climbing pinion for meshing with a corresponding toothed rack, the method including providing a load monitor of each drive unit of each chord with at least one strain sensing apparatus on a selected pinion of each drive unit of each rack-and-pinion leg jacking system of each chord; with each strain sensing apparatus, sensing strain on the selected pinion, said strain indicative of a load on the associated leg and producing a signal indicative thereof related to each drive unit of each chord; transmitting said signals to a control system, and processing said signals to produce a value of load on each leg and a total load value for a platform load comprising total load on the platform; displaying in real time on a display any sensed load and/or the platform load and/or measurements for each leg; within the control system, comparing said values to specified values for each leg and for the platform, if said specified valve is exceeded for any individual leg or for total platform load, producing an alarm for a system operator; wherein the at least one strain sensing apparatus is a plurality of strain gauges, maintaining a

first historical record of load measurements for each leg and for platform load, with the control system, providing access to the first historical load record, the control system including, for each leg, a programmable logic controller for processing signals indicative of load, each programmable logic controller in wired communication with the at least one strain sensing apparatus, processing the signals indicative of load with the programmable logic controllers, providing a rack path differential monitoring system for indicating rack path differential for the toothed racks of the legs of the platform, wherein the oilfield platform has a deck, detecting relative position of each chord with respect to the deck to thereby identify possible twisting of each leg, providing a display in real time of displacement between each chord and the platform, maintaining in the control system a second historical record of displacements between each chord and the platform, and with the control system, providing access to the second historical record.

The present invention discloses in some, but not necessarily all, embodiments a system for monitoring load on a chord of a leg of an oilfield platform, the chord with a corresponding toothed rack, a rack-and-pinion leg jacking system for the chord for jacking the leg up and down, the rack-and-pinion leg jacking system with a plurality of drive units, each drive unit having a motor, a gear system with pinions, and a climbing pinion for meshing with the toothed rack, the system including: a load monitor for each drive unit with at least one strain sensing apparatus on a selected pinion of each drive unit, for sensing strain on the selected pinion, said strain indicative of load on the associated chord and

producing a signal indicative thereof; a control system; transmission apparatus for transmitting said signal to the control system; and the control system for processing said signal to produce a value of load on said chord.

The present invention discloses in some, but not necessarily all, embodiments a system for monitoring legs of an oilfield platform, the platform having a plurality of legs, each leg with a plurality of chords, each chord with a corresponding toothed rack, a rack-and-pinion leg jacking system for each chord for jacking the legs up and down, each rack-and-pinion leg jacking system with a plurality of drive units, each drive unit with a motor, gear system with pinions, and a climbing pinion for meshing with a toothed rack of a chord, the system including: a load monitor of each drive unit with at least one strain sensing apparatus on a selected pinion of the drive unit for sensing strain on the selected pinion, said strain indicative of load on the associated chord and producing signals indicative thereof; a control system; transmission apparatus for transmitting said signals to the control system; the control system for processing said signals to produce a value of leg load on each leg and platform load on the platform; and said control system for comparing said values to specified values for leg load and for platform load, and if any specified value is exceeded for either leg load or for platform load, the control system for producing an alarm for a system operator. Such a system may have one or some any possible combination of the following: the at least one strain sensing apparatus is a plurality of strain gauges; the control system includes, for each leg, a programmable logic controller for processing signals indicative of load, each programmable logic controller in

wired communication with all strain sensing apparatus for a corresponding leg, and the programmable logic controllers for processing the signals indicative of load; rack path differential monitoring apparatus for detecting relative position of each chord within respect to a deck of the oilfield platform to thereby identify possible twisting of each leg, and for providing a signal from each measurement apparatus to an associated programmable logic controller of the control system for determining the displacement between each chord and the platform; and/or maintaining in the control system an historical record of displacements between each chord and the platform, and the control system for providing access to the historical record.

CLAIMS:

1. A method for monitoring a jack-up rig comprising a platform, at least one leg, at least one chord having a toothed rack and a jacking apparatus comprising a climb pinion apparatus driven by a motor for jacking the platform on the at least one leg, the climb pinion apparatus comprising a gear for meshing with the toothed track and a shaft, wherein at least one strain sensing apparatus is provided on said climb pinion apparatus, the method comprising the steps of obtaining a signal indicative of strain with said strain sensing apparatus and a signal indicative of a load on said motor, sending said signals to a control system, and processing said signals to produce a value of a load on said chord.

2. A method in accordance with Claim 1, wherein said strain sensing apparatus is located on said shaft, the method comprising the step of using said strain sensing apparatus to sense strain in said shaft to produce said signal indicative of strain.

3. A method in accordance with Claim 1 or 2, the climb pinion apparatus further comprising at least one further gear and a further shaft wherein said at least one strain sensing apparatus is arranged on said further shaft, the method comprising the step of using said strain sensing apparatus to sense strain in said further pinion to produce said signal indicative of strain.

4. A method in accordance with Claim 1 or 2, the climb pinion apparatus further comprising at least one further gear and a further shaft

wherein said at least one strain sensing apparatus is arranged on said further gear, the method comprising the step of using said strain sensing apparatus to sense strain in said further gear to produce said signal indicative of strain.

5. A method in accordance with any preceding claim, wherein said strain sensing apparatus is located on said gear, the method comprising the step of using said strain sensing apparatus to sense strain in said gear to produce said signal indicative of strain.

6. A method in accordance with any preceding claim, wherein the at least one strain sensing apparatus is a plurality of strain gauges.

7. A method in accordance with any preceding claim, further comprising the step of displaying on a display a load measurement for said chord.

8. A method in accordance with any preceding claim, wherein said at least one strain sensing apparatus forms part of a load monitor.

10. A method in accordance with any preceding claim, further comprising the step of comparing said value of a load on said chord with a specified value and if said value of a load on said chord is greater than said specified value, activating an alarm.

9. A method in accordance with any preceding claim, further comprising the step of maintaining a historical record of value of a load on said chord and accessing the historical record using said control system.

11. A method in accordance with Claims 9 and 10, wherein said specified value is derived from a historical value obtained from the historical record.

12. A method in accordance with any preceding claim, further comprising the step of measuring rotation of said gear with rotation measuring apparatus to obtain a displacement signal indicative of linear displacement of said platform relative to said leg and sending said displacement signal to said control system and processing said displacement signal to produce a value of a linear displacement of said platform relative to said leg.

13. A method in accordance with any preceding claim, wherein the jacking apparatus is suspended in or on a resilient member on said platform the method further comprising the step of measuring vertical displacement of each jacking apparatus in relation to said platform using a distance measuring device.

14. A method in accordance with any preceding claim, further comprising at least a second leg, at least one second chord having a second toothed rack and a second jacking apparatus comprising a second climb pinion apparatus driven by a second motor for jacking the platform on the second leg, the second climb pinion apparatus comprising a second gear for meshing with the second toothed track and a second shaft, characterised in that at least a second strain sensing apparatus is provided on said second climb pinion apparatus the method comprising the steps of obtaining a second signal indicative of strain with said strain sensing apparatus

and sending said second signal to a control system and processing said second signal to produce a value of a load on said second chord.

15. A method in accordance with Claim 14, further comprising providing a rack path differential monitoring system for monitoring rotation of each pinion to provide an indication of a linear displacement of each selected pinion of each chord and the leg associated therewith for comparison to indicate rack path differential for the legs of the platform.

16. An apparatus for monitoring a jack-up rig comprising a platform, at least one leg, at least one chord having a toothed rack and a jacking apparatus comprising a climb pinion apparatus driven by a motor for jacking the platform on the at least one leg, the climb pinion apparatus comprising a gear for meshing with the toothed track and a shaft, wherein at least one strain sensing apparatus is provided on said climb pinion apparatus for obtaining a signal indicative of strain with said strain sensing apparatus and sending said signal to a control system, the apparatus further comprises a load measuring apparatus for measuring a load on the motor to produce a motor load signal indicative of the load on the motor and sending the motor load signal to the control system, and the control system is configured for processing said signals to produce a value of a load on said chord.

17. A system for monitoring a jack-up rig comprising a platform, at least one leg, at least one chord having a toothed rack and a jacking apparatus comprising a climb pinion apparatus driven by a motor for jacking the

platform on the at least one leg, the climb pinion apparatus comprising a gear for meshing with the toothed track and a shaft, wherein at least one strain sensing apparatus is provided on said climb pinion apparatus for obtaining a signal indicative of strain with said strain sensing apparatus and sending said signal to a control system, the system further comprises a load measuring apparatus for measuring a load on the motor to produce a motor load signal indicative of the load on the motor and sending the motor load signal to the control system, and the control system is configured for processing said signals to produce a value of a load on said chord.