

## ARRANGEMENT AND METHOD FOR HEAVE COMPENSATION OF TOOLS PROVIDED WITH VERTICAL RACK GEARING IN A DERRICK

The invention relates to an arrangement and a method for heave compensation of a working unit which includes at least one driving unit and is arranged in a vertically displaceable manner in a derrick by said at least one driving unit being in engagement with a pitch rack arranged vertically in the derrick.

On floating surface installations that are used for operations with equipment which is placed on the sea floor or in a subsea borehole or well, for example for extracting hydrocarbons, there is often a need to use heave compensation, so that the equipment depending from the floating surface installation will not move uncontrolledly because of movement of the surface installation induced by waves or oceanic currents. The heave compensation is typically provided by means of winches or hydraulic cylinders, which are connected to an elongated element to which the equipment is attached, for example in the form of a wireline or a pipe string. For example, it is known to hang a top-drive drilling machine on a complex system of wires, pulleys and winches to prevent a drill bit from being subjected to uncontrolled vertical movement owing to the wave-induced movement of a drilling vessel.

The invention has for its object to remedy or reduce at least one of the drawbacks of the prior art or at least provide a useful alternative to the prior art.

The object is achieved through the features that are specified in the description below and in the claims that follow.

The invention provides a tower, especially a derrick, which includes several guiding tracks for a connected working unit, for example a pipe winch, a drilling machine, power tongs, a slips arrangement, a circulation unit for drilling fluid or a work platform, and combinations of working units, so that said working unit may be moved up and down the tower to generate a vertical displacement of an attached tool, for example a pipe string with an appurtenant downhole tool. The vertical travel of the working unit is brought about by one or more driving units engaging with at least one pitch rack arranged vertically in the tower. The position of the working unit in the horizontal direction may be determined by the engagement of the working unit in the guiding tracks, typically provided by supporting means in the form of rollers and/or guide shoes resting against the guiding tracks.

The at least one pitch rack is hung off in a heave compensator. Preferably, the heave compensator is one or more rotary actuators, typically in the form of electric or hydraulic motors, engaging with the at least one pitch rack. In a manner known *per se*, the heave compensator includes a control system, which is arranged to register heave movements of the tower and generate control signals for the rotary actuator(s) so that the heave movements of the tower are neutralized by the pitch rack being moved in a vertical direction.

Advantageously, the pitch rack is provided with toothings on two opposite sides for abutment against respective gears connected to the rotary actuator(s) of the heave compensator and to the driving unit(s) of the working unit. A heave compensator may be connected to several pitch racks by means of suitable transmission means, for example mechanical gearboxes and hydraulic systems.

It is an advantage if the rotary actuators of the heave compensator are identical.

It is an advantage if the driving units of the working unit are identical.

It is an advantage if the heave compensator is arranged in an upper tower portion.

The invention is defined by the independent claims. The dependent claims define advantageous embodiments of the invention.

In a first aspect, the invention relates more specifically to an arrangement for heave compensation of a working unit, thereby compensating heave motion of a floating surface installation on which the working unit is installed, the working unit including at least one driving unit and being arranged in a vertically displaceable manner in a tower by said at least one driving unit being in engagement with a pitch rack arranged vertically in the tower, characterized by the pitch rack being hung off in a vertically displaceable manner in a heave compensator arranged in an upper tower portion, the pitch rack depending from the heave compensator.

The heave compensator may include at least one rotary actuator taken from a group comprising hydraulic motors and electric motors. Thereby a compact and not very space-demanding heave compensator is provided.

The pitch rack may be provided with two opposite rows of teeth, and the heave compensator may include at least one rotary actuator in engagement with each of the rows of teeth. Thereby a plurality of cooperating rotary actuators may be used in the heave compensator, and, because of that, the size of each of the rotary actuators may be reduced. Besides, space may be allowed for back-up actuators, which may come into function as soon as a malfunction is registered in the functioning of a rotary actuator in normal operation.

The rotary actuator(s) may be connected to a mechanical or hydraulic transmission via a remote-controlled clutch. Thereby the function of the heave compensator may be maintained even if there should be a malfunction and blocking of one of the rotary actuators.

5 The tower may include several parallel pitch racks, whose vertical displacements are synchronized by the pitch racks being interconnected by a mechanical or hydraulic transmission for generating the cooperating displacements of the pitch racks by means of at least one rotary actuator connected thereto. Alternatively, the tower may include several parallel pitch racks whose vertical displacements are synchronized by each pitch rack being connected to an electronic position-monitoring system connected to a control system for the heave compensator for generating individual displacement of each pitch rack or group of pitch racks by means of at least one rotary actuator connected to each pitch rack or group of pitch racks.

In a second aspect, the invention relates more specifically to a method of heave-compensating a working unit, thereby compensating heave motion of a floating surface installation on which the working unit is installed, the working unit including at least one driving unit and being arranged in a vertically displaceable manner in a tower by said at least one driving unit being in engagement with a pitch rack arranged vertically in the tower, characterized by the method comprising the steps:

15 a) arranging a heave compensator in an upper portion of the tower;  
 b) hanging off the pitch rack in the heave compensator;  
 c) registering a heave movement in the tower by means of a control system connected to the heave compensator;  
 20 d) displacing the pitch rack vertically by means of the heave compensator in order thereby to neutralize the heave movement of the tower.

The method may further include:

e) hanging off several pitch racks in the same heave compensator; and  
 25 f) moving the pitch racks synchronously by  
     f<sub>1</sub>) connecting the pitch racks to a mechanical or hydraulic transmission, and moving the pitch racks collectively, or  
     f<sub>2</sub>) connecting each pitch rack to an electronic position-monitoring system connected to a control system for the heave compensator, and displacing each pitch rack individually.

30 In what follows, an example of a preferred embodiment is described, which is visualized in the accompanying drawings in which:

Figure 1 shows a side view of a tower with a drilling machine vertically displaceable along guiding tracks in the tower and in engagement with a pitch rack hung off in a heave compensator arranged in an upper portion of the tower;

- Figure 2 shows, on a larger scale, a side view of an upper portion of a dual tower with respective pitch racks hung off in a heave compensator;
- Figure 3 shows, in perspective, a working unit in the form of a drilling machine arranged to be vertically displaceable along guiding tracks in the tower and in engagement with a pitch rack;
- Figure 4 shows, in perspective, an upper portion of a dual tower with respective pitch racks hung off in a heave compensator, the operation of rotary actuators that are in engagement with the respective pitch racks being synchronized by them being connected in pairs to a mechanical transmission; and
- Figure 5 shows, in perspective, an upper portion of a dual tower with respective pitch racks hung off in a heave compensator, the operation of rotary actuators that are in engagement with the respective pitch racks being synchronized by means of electronic monitoring of the positions of the pitch racks.

A tower 2 projects up from a deck 11 on a floating surface installation 1 or vessel, shown schematically in figure 1. A working unit 3, shown here as a drilling machine, is vertically displaceable along guiding tracks 22 on the tower 2, and several driving units 33, shown here as motors 331, are in engagement with a pitch rack 23 and are arranged to move, for example, a downhole tool (not shown) arranged at a remote end of a pipe string or another elongated body (not shown). The pitch rack 23 is hung off in a heave compensator 24 connected to the tower, shown in the exemplary embodiment as arranged in an upper portion 21 of the tower 2. An upper end portion 235 of the pitch rack 23 projects freely up above the heave compensator 24. The heave compensator 24 includes several rotary actuators 241, typically in the form of electric or hydraulic motors that are connected to an energy supply unit (not shown) and a control system 243 which comprises the necessary elements (not shown) for registering the heave movements of the floating installation 1 and generating control instructions to the rotary actuators 241 of the heave compensator 24.

The pitch rack 23 is vertically displaceable by means of the heave compensator 24 as the heave compensator 24 neutralizes the heave movements of the surface installation 1 in a manner known *per se*. The pitch rack 23 is provided with a first row of teeth 231, which is in engagement with driving gears 332 on the rotary actuator(s) 331 of the working unit 3 and with corresponding driving gears 241' connected to the rotary actuator(s) 241 of the heave compensator 24. Preferably, the pitch rack 23 is double, that is to say it is provided with two opposite rows of teeth 231, 232 (only one is visible in the figures). It is an advantage if support is arranged right opposite the driving gears 332 and 241', respectively, in order to take up the force component that the displacements of the working unit 3 on the pitch rack 23 and the pitch rack 23 relative to the heave compensator 24, respectively, generate normal to the longitudinal axis of the pitch rack 23. When the pitch rack 23 is provided with two opposite rows of teeth 231, 232, two rotary actuators 241 and 331, respectively,

may appropriately be arranged right opposite each other and on respective sides of the pitch rack 23 both in the heave compensator 24 and in the working unit 3, as appears clearly from figures 3, 4 and 5, or, possibly, via a suitable transmission (not shown), at least driving gears 241' and 332, respectively, may be arranged right opposite each other on respective sides of the pitch rack 23.

5 The working unit 3 is provided with several supporting means 32, typically supporting rollers (shown here) and/or guide shoes resting against respective guiding tracks 22 on the tower 2 and positioning the working unit 3 accurately in the horizontal plane. The pitch rack 23 may therefore depend freely from the heave compensator 24, as it does not contribute in the horizontal positioning of the working unit 3. On the contrary, the position of the pitch rack 23 in the horizontal plane is  
10 controlled by the working unit 3.

Reference is now made particularly to figures 2 and 4, in which upper portions 21, 21' of first and second towers 2, 2' are interconnected, and in which the heave compensator 24 includes several rotary actuators 241, which are connected in pairs via a mechanical transmission 242. The transmission, which may also be formed as a hydraulic arrangement, ensures that the heave compensa-  
15 tion of first and second pitch racks 23, 23' is synchronized. Correspondingly, a tower may include several pitch racks (not shown) for the suspension of one and the same working unit, or, possibly, different working units may each be suspended from a respective pitch rack.

Reference is now made to figure 5, in which the heave compensation of two pitch racks 23, 23' is synchronized electronically by the heave compensator 24 being provided with a system 244 for  
20 monitoring the positions of the pitch racks 23, 23', for example by each pitch rack 23, 23' being provided with position indicators 234 readable by the position-monitoring system 224 which then supplies the control system 243 of the heave compensator 24 with control data, and the rotary actuator 241 of each pitch rack 23, 23', possibly sets of several rotary actuators 241, is/are operated to displace the respective pitch racks 23, 23' in a synchronous manner.

25 When a working unit 3, which is arranged in a tower 2 with heave compensation like that described above, has been connected to a pipe string or some other elongated body (not shown) with which an attached downhole tool (not shown) or the like is to be displaced or held in position, the working unit 3 is displaced or positioned relative to the pitch rack 23. Independently of the travel of the working unit 3 along the pitch rack 23, said pipe string / elongated body, not shown, may remain  
30 unaffected by possible heave motion in the floating surface installation 1 and the tower 2 by the heave compensator 24 displacing the pitch rack 23 relative to the tower 2, neutralizing the heave motion. Other working units (not shown) that are possibly arranged in the tower 2, possibly in the second, adjacent, tower 2' to cooperate with the working unit 3 shown may be displaced vertically in the same way on the same pitch rack 23, possibly on the second pitch rack 23' at the same time  
35 as it is heave-compensated synchronously with the working unit 3 shown.

Even though the exemplary embodiment shows a pitch rack 23 depending from a heave compen-

sator 24 arranged in an upper portion 21 of a tower 2, this does not exclude an arrangement in which the heave compensator 24 is arranged in a lower portion 25 of the tower or below the deck 11 from which the tower 2 rises. The advantage of an arrangement like that not shown is that a heavy element like the heave compensator 24 will then have a lower centre of gravity, which in-  
5 creases the stability of the floating surface installation 1. The drawback is that the pitch rack 23 must be secured against buckling with guides or an increased cross section, which increases the weight of the pitch rack.

It should be noted that all the above-mentioned embodiments illustrate the invention, but do not limit it, and persons skilled in the art may construct many alternative embodiments without depart-  
10 ing from the scope of the attached claims. In the claims, reference numbers in parentheses are not to be regarded as restrictive. The use of the verb "to comprise" and its different forms does not exclude the presence of elements or steps that are not mentioned in the claims. The indefinite article "a" or "an" before an element does not exclude the presence of several such elements.

The fact that some features are indicated in mutually different dependent claims does not indicate  
15 that a combination of these features cannot be used with advantage.

## C l a i m s

1. An arrangement for heave compensation of a working unit (3), thereby compensating heave motion of a floating surface installation (1) on which the working unit (3) is installed, the working unit including at least one driving unit (33) and being arranged in a vertically displaceable manner in a tower (2) by said at least one driving unit (33) being in engagement with a pitch rack (23) arranged vertically in the tower (2), c h a -  
5 r a c t e r i z e d i n that the pitch rack (23) is hung off in a vertically displaceable manner in a heave compensator (24) arranged in an upper tower portion (21), the pitch rack (23) depending from the heave compensator (24).
- 10 2. The arrangement according to claim 1, wherein the heave compensator (24) comprises at least one rotary actuator (241) taken from a group comprising hydraulic motors and electric motors.
3. The arrangement according to claim 1, wherein the pitch rack (23) is provided with two opposite rows of teeth (231, 232), and the heave compensator (24) comprises at least  
15 one rotary actuator (241) in engagement with each of the rows of teeth (241, 242).
4. The arrangement according to claim 1, wherein a rotary actuator (241) is connected to a mechanical or hydraulic transmission (242) via a remote-operated clutch (242').
5. The arrangement according to claim 1, wherein the tower (2) includes several parallel pitch racks (23), whose vertical displacements are synchronized by the pitch racks (23) being interconnected by a mechanical or hydraulic transmission (242) for generating the  
20 cooperating displacements of the pitch racks (23) by means of at least one associated rotary actuator (241).
6. The arrangement according to claim 1, wherein the tower (2) includes several parallel pitch racks (23) whose vertical displacements are synchronized by each pitch rack (23) being connected to an electronic position-monitoring system (244) connected to a  
25 control system (243) for the heave compensator (24) for the generation of displacement of each pitch rack (23) by means of at least one rotary actuator (241) connected to each pitch rack (23) or group of pitch racks (23).
7. A method of heave-compensating a working unit (3), thereby compensating heave  
30 motion of a floating surface installation (1) on which the working unit (3) is installed, the working unit including at least one driving unit (33) and being arranged in a vertically displaceable manner in a tower (2) by said at least one driving unit (33) being in engagement with a pitch rack (23) arranged vertically in the tower (2), c h a -  
r a c t e r i z e d i n that the method comprises the steps:

- a) arranging a heave compensator (24) in an upper portion (21) of the tower (2);
- b) hanging off the pitch rack (23) in the heave compensator (24);
- c) registering a heave movement in the tower (2) by means of a control system (243) connected to the heave compensator (24);
- 5 d) displacing the pitch rack (23) vertically by means of the heave compensator (24) in order thereby to neutralize the heave movement of the tower (2).

8. The method according to claim 7, wherein the method further includes:

- e) hanging off several pitch racks (23) in the same heave compensator (24); and
- f) moving the pitch racks (23) synchronously by
  - 10 f<sub>1</sub>) connecting the pitch racks (23) to a mechanical or hydraulic transmission (242), and moving the pitch racks (23) collectively, or
  - f<sub>2</sub>) connecting each pitch rack (23) to an electronic position-monitoring system (244) connected to a control system (243) for the heave compensator (24), and displacing each pitch rack (23) individually.