Title: Jacking system for a leg of a jack-up platform

The invention relates to jack-ups platforms. More particularly the invention relates to a jacking system applied on a jack-up platform for near shore and offshore installation, drilling, maintenance, deployment and for decommissioning of offshore structures such as gas and oil platforms, subsea structures, wind energy generating structures and/ or other offshore structures.

Generally the jacking systems of jack-up platforms consist of either: continuous system like rack and pinion systems or winch and wire systems or: discontinuous systems working with actuators such as hydraulic cylinders in mainly two modes.

The first mode: the load of the leg is carried by the hydraulic cylinder and the second mode where the leg is locked to the platform while the hydraulic cylinders make their return stroke.

The jack-up platform is brought to its offshore location afloat. At location it is able to rise out of the water and stand above the waves. The jacking system provides the connection between the jack-up leg and the jack-up platform. The jacking system is able to lower and raise the legs. When the legs are in contact with the seafloor, the jacking system will eventually raise and lower the platform.

A discontinuous jacking system with hydraulic cylinders is generally more economical than a continuous system like rack and pinion and winch and wire system. On the other hand, due to the intermittent operation, the system is slow.

It is the object of the current invention to provide a jacking system and a method of jacking that is faster while maintaining the advantages of known systems.

A first aspect of the invention is Jacking system for a leg of a jack-up platform, comprising at least three independent yokes, each yoke is connected to a jack-up structure by at least one vertically arranged double acting

actuator and is equipped with a leg engaging mechanism such as a horizontally arranged movable locking pin, which is configured to engage or to disengage with a hole of the jack-up leg, in order to transfer a load from the jack-up platform to the leg, including a controller configured to operate the yokes in a way that the leg is moved by all the at least three yokes in an alternating mode, such that at any moment in time during operation all but one of the at least three yokes take the load via the associated engaging mechanism, while the remaining yoke of the at least three yokes makes a return stroke with its engagement mechanism in a disengaged position. Another aspect of the invention is a Method for moving a leg of a jack up platform comprising the steps of providing a jacking system according to any of claims 1-8; associating the jacking system with a leg of a jack up platform; disengaging an engagement mechanism of a remaining yoke from a hole of the leg while maintaining the engagement of the yokes that are load bearing; actuating the actuators of the engaged yokes, while returning the first disengaged yoke in its original position; re-engaging the first yoke and disengaging a second yoke; repeating the above steps for each consecutive yoke, one at a time, thus moving the leg in an upright direction.

Further advantageous aspects of the invention can be found in the dependent claims.

For a better understanding, embodiments of the jacking system will be further elucidated by the following Figures, wherein:

Fig. 1 is a schematic side view of a jack up platform;

Fig. 2 is a schematic top view of a jack up platform;

Fig. 3 is a partly worked open schematic side view of a jack up system as known in the art;

Fig. 4 is a schematic top view of a jack up system as known in the art;

Fig. 5 is a schematic top view of a jack up system according to a first embodiment of the invention;

Fig. 6 is a partly worked open side view of a further embodiment of the invention;

Fig 7 is a schematic rolled out view of the jack up system according to a further embodiment of the invention;

Fig. 8 is a schematic top view of a jack up system according to a further embodiment of the invention; and

Fig. 9 is schematic partly cut open side view of the further embodiment presented in figure 8.

In the figures and the description the same or corresponding parts will have identical or similar reference signs. The embodiments shown should not be understood as limiting the invention in any way or form.

Figures 1 and 2 represent respectively a side and a top view of a typical jack up platform 1, wherein a platform structure 2 can be lowered and raised relative to the legs 3. The structure 2 of the platform can be typically a barge or a pontoon. In figures 1 and 2, the platform is provided with 4 legs. Each of the legs 3 is connected to the deck of the platform by means of a jacking system 4, incorporated in a jack up structure such as a jack-house 5. The jack-house is in general affixed to the platform structure 2 and transfers the loads of the structure 2 and eventual additional loads exerted to the structure 2 to the seabed through the legs 3. Each leg is moved by a jacking system 4 which is housed in a jack-house 5. The jack-house is normally a plate construction and it may be part of the platform structure 2.

Although 4 legs 3 are shown, more or less legs 3 might be applied similarly, even a platform with one leg 3 might be provided with a jacking system 4.

Figure 3 represents a partly worked open side view of a jacking system 4 as known in the art. This is a typical discontinuous jacking system, wherein the vertical movements of the legs 3 relative to the platform structure 2 is performed in an intermittent motion.

The jacking system 4 consists of basically two yokes 6,7 an upper 6 and a lower 7 yoke, connected by two hydraulic cylinders 8. Each yoke 6,7 is equipped with a locking pin 9, 9' which can be engaged in a hole 11a-11j in the leg wall 3a to transfer the vertical load L. In figure 3 a cross section of the jack-house 5 is shown in which an arrangement with a fixed upper yoke 6 and a moveable lower yoke 7 is positioned. The lower yoke 7 can be moved by two hydraulic cylinders 8. The locking pin 9 and 9' are positioned in the centre of the yokes 6 and 7 respectively. The locking pins 9 and 9' can be actuated by separate small hydraulic cylinders 10a-10d.

In figure 4, the jack-house 5 with the jacking system 4 is depicted in a cross sectional top view. In this figure, an arrangement with 3 upper yokes 6 and 3 lower yokes 7 and thus 6 hydraulic cylinders 8 is shown.

Each yoke 6, 7 is in balance, meaning that an imaginary straight line IL runs through the centers of the two cylinders 8 and the centre CK of the contact area of the locking pin 9 inside the leg hole 11.

Normally the three yokes work in parallel.

In the jacking modes:

- the locking pin 9' of lower yoke 7 is brought in a leg engaging position by cylinder 10'
- the locking pin 9 of the upper yoke 6 is brought in a disengaged position by cylinder 10
- the cylinders 8 push the leg 3 downwards, until the end of the stroke of the cylinder, being equal to pitch, i.e. the vertical distance between the holes 11a-11b.
- the locking pin 9 of the upper yoke 6 is brought in the leg engaging position by cylinder 10 and the upper yoke 6 takes over the load
- the locking pin 9' of the lower yoke 7 is brought in a disengaged position and the cylinders 8 make a return stroke. During this return stroke the legs 3 are not moving with respect to the platform structure 2.

Because of the return stroke, the effective jacking speed of one individual leg is approx 60% to 70% of the nominal cylinder speed during jacking.

The installed hydraulic power (including motor, pump valves, piping etc) needed for jacking shall be designed for the nominal cylinder velocity. During the return stroke, the platform structure 2 is in rest and only reduced power is needed for the return speed.

Each of the jacking systems 4 follows the same sequence of motions. However, when the seafloor is uneven or when the leg foot penetrations into the seafloor are uneven, the legs 3 might have a different position relative to the platform structure 2.

In order not to twist the platform 1 to an unacceptable level and in order to ensure an even load in each of the legs 3, it might be necessary to stop all jacking systems 4 when one of the systems 4 makes a return stroke.

Due to this phenomenon, the effective jacking speed might be as low as half the normal jacking speed of an independent leg 3.

The load capacity of a jacking system 4 of a jack-up leg 3 shall be designed for two main conditions:

- elevating (mainly static)
- pre-loading / storm survival (static plus dynamic)

During the elevating condition, the platform structure 2 must be lifted out of the water. The jacking systems 4 of all legs 3 together should carry the weight of the platform structure 2 including some system friction.

During the elevating operation, the weather condition of waves, current and wind are fair. The environmental loads on the platform 1 are normally relatively small.

During the storm survival conditions the jack-up platform 1 stands safe above the waves. The platform 1 is loaded only by wind. The legs 3 are loaded by wind, current and waves. The environmental loads result in a extra vertical load in the legs 3.

In order to ensure that the bearing capacity of the soil at the leg tip is sufficient, the expected vertical storm survival load plus some allowance shall be applied once during pre-loading. Pre-loading is therefore a standard part of the installation procedure of the platform. Accordingly, the pre-load of a jacking system 4 is always higher than the nominal jacking load. Thus the cylinders 8 of a jacking system 4 as described before should be designed and certified for the pre-load condition. Consequently, during normal jacking, the capacity of the cylinders is only partly used.

The invention includes a faster jacking system and a more economical use of the hydraulic cylinder capacity.

The invention is described with the help of figures 5, 6 and 7.

In figure 5, the jacking system 4 includes a circular leg 3 with four independent yokes 7a, 7b, 7c and 7d. Each yoke 7a, 7b, 7c and 7d is operated by two hydraulic cylinders 8a, 8a', 8b, 8b', 8c, 8c', 8d, 8d' respectively. Each yoke 7a, 7b, 7c and 7d is equipped with a locking pin 9a, 9b, 9c, 9d which is operated by a small hydraulic cylinder 10a, 10b, 10c and 10d respectively.

During jacking, three out of four yokes 7a, 7b, and 7c are in engagement with the leg 3 by means of the locking pins 10a, 10b and 10c respectively. The jacking load is carried by these three yokes 7a, 7b and 7c. During jacking, the fourth yoke 7d is disengaged and makes a return stroke at a speed S2 higher than the jacking speed S1 (see figure 7).

In figure 7, a schematic rolled out projection of jacking system as presented in figure 6 is given. In figure 7, the different positions of the hydraulic cylinders 8a-8d' and the yokes 7a-7d are depicted one next to each other.

In figure 6 and 7, the various yokes 7a, 7b, 7c and 7d are in different positions e.g.:

- the first yoke 7a might be at ¼ of the cylinder stroke
- the second yoke 7b might be at ½ of the cylinder stroke
- the third yoke 7c might be at ¾ of the cylinder stroke

- the fourth yoke 7d is then approximately half way the return stroke

The return yoke 7d can automatically engage when it reaches the hole 11e in the leg 3. When the locking pin 9d engaged hole 11e, the jacking stops and the furthest extended yoke 7c can be disengaged from hole 11b. Then the jacking may continue, wherein now the yokes 7a, 7b and 7d are bearing load, whereas yoke 7c is returning to its retracted state.

By this way of alternating of the returning yoke, the stops are limited to a few seconds only.

The eight jacking cylinders 8a-8d' are preferably identical and are suspended at preferably the same level from the inside roof 14 of the jack-house 5.

The different positions of the yokes 7a-7d are possible because the holes 11a-11j in the leg 3 on different vertical positions in a helical or spiral type pattern. A possible arrangement of the leg holes and the yokes is shown in figures 6 and 7.

During pre-loading and during storm survival conditions, all four yokes 7a-7d are engaged and the leg load is distributed over eight cylinders 8a-8d'.

By the arrangement as described above, the advantages are that a high jacking speed can be obtained while at same time the installed hydraulic power can be fully used. Furthermore, an effective use of cylinder capacity in jacking mode and survival mode can be obtained. Beside these advantages, for the system as descried above, a reduced number of parts is needed, for instance because no upper yokes 6 are needed.

The above description is based on a jacking system 4 with a closed circular leg 3 and four jacking yokes 7a-7d, including 8 cylinders 8a-8d'. The same principle can be applied in a square or triangular truss type leg or on any closed cylindrical leg with a triangular, square, hexagonal or octagonal cross section.

Although in the description and the figures each yoke 7a-7d is provided with one locking pin 9a-9d, the same principle applies also on a system with two or more locking pins in each yoke. Similarly, although each yoke 7a-7d is provided with two cylinders 8a-8d', each yoke can also be equipped with more than two cylinders, like for example four cylinders per yoke.

Besides the above described jacking sequence of the individual yokes 7a-7d, the jacking system 4 can also be operated in a continuous way. The locking pin 10 of the yoke 7 in the return stroke can for instance engage the leg hole 11 automatically as soon as it reaches the appropriate hole 11a-11j in the leg 3.

When the pin 9a-9d passes the leg hole 11a-11j, it will be pressed into the hole and the yoke7a-7d will automatically follow the leg at low pressure oil. When one of the other yokes reaches the end of its cylinder stroke, the jacking system 4 stops in order to disengage the locking pin. This action only takes a few seconds.

During this action the jacking systems 4 of the other legs 3 may continue their movement. The uneven jacking speed of the various legs 3 might cause a small twist deformation of the platform, which is acceptable. Only when the disengagement takes longer than a few seconds for whatever reason, the other jacking systems should stop.

By the arrangement of the jacking system 4 as described above, the effective average jacking speed can be almost (e.g 95%) as high as the cylinder speed.

The jacking system can be made continuous and at constant speed by adding a control mechanism as follows.

When the yoke with the most extended cylinders reaches the end of the stroke, the speed of that yoke will be slightly increased relative to the other yokes in a way that the locking pin is unloaded and can be disengaged.

As soon as the locking pin is disengaged, the speed of the cylinders of that yoke can be reversed for the return stroke.

A hydraulic piping system connects the various parts like hydraulic cylinders, valves, pumps and reservoirs. This piping system can be arranged in a way that during jacking, high pressure hydraulic oil is pumped to the bottom side of three out of four pairs of cylinders.

The low pressure ring side of the three pairs of pushing cylinders is connected to the ring side of the single pair of cylinders in the return mode.

The ring side flow of three pairs of active cylinders is sufficient to bring the pairs of cylinders performing the return stroke back in the start position with some time allowances. In this way no extra pump is needed for the return stroke.

During jacking with three out of four yokes, the total jacking force is applied outside the centre of the leg at approx 1/6 of the leg diameter.

This eccentric jacking force causes a moment in the jack-up leg. This moment can be counteracted by the upper 12 and lower 13 leg guide, as is shown in figure 6.

The typical distance between the leg guides 12 and 13 is 4 times the leg diameter. The horizontal reaction force at each of the guides can be 1/6 x ¼ = 1/24 of the jacking force.

The friction coefficient is conservatively estimated at 0.3. The vertical friction force is than calculated at 1/24 x 2 x 0.3 = 0.025 x jacking force. This extra friction force of approx 2.5% is acceptable.

In order to prevent rotation of the leg 3 relative to the platform structure 2 a rotation prevention can be installed. The rotation prevention provision is for example advantageous when the legs have a circular cross section.

External forces and moments may cause rotation of the leg around its vertical axis. The jack-up leg should be locked against this rotation in order to ensure that the alignment of the locking pins and the holes in the jack-up

leg is correct. The invention includes locking against rotation. The locking is ensured by static vertical guidance pillars inside the jack-house and guidance shoes on the yokes 7a-7d.

In figure 8, in a further embodiment four guidance pillars 14a, 14b, 14c, 14d are provided. The pillar 14a can slide between the shoes 15a'and 15b, the pillar 14b can slide between the shoes 15b'and 15c, the pillar 14c can slide between the shoes 15c' and 15d, and finally the pillar 14d can slide between the shoes 15a and 15d'. It is advantageous to have two guidance pillars 14a-14d per yoke 7a-7d and to have two shoes 15a-15d' on each pillar 14a-14d. The guidance pillars 14a-14d for the several yokes 7a-7d, can be combined in a way that the number of guidance pillars 14a-14d is equal to the number of yokes 7a-7d, as is depicted in figure 8.

The vertical guidance pillars 14a-14d can be arranged over a height slightly larger than the stroke of the yokes 7a-7d. For example between a tweendeck 16 in the jack-house 5 and the maindeck of the platform 1 as can be seen in figure 9.

The guidance pillars 14a-14d can be fixed at upper and lower end to the tweendeck 16 in the jack-house 5 and to the maindeck.

The system of yokes 7a-7d and locking pins 9a-9d requires strict tolerances. Very good tolerances can be reached by the system below. In order to follow the horizontal deflection of the leg, the guidance pillars 14a-14d can horizontally be guided by the leg 3. This can be arranged by an upper ring 17 at tweendeck level and a lower ring 18 just above maindeck level.

The guidance pillars 14a-14d and the rings 17 and 18 are fixed to each other. The inside of the both rings 17 and 18 is guided by the leg 3 with a small tolerance. The construction of pillars 14a-14d and rings 17 and 18 is connected to maindeck and tweendeck 16 in a way that it is supported in vertical V and tangential direction T, but is free in radial direction R.

The upper ring 17 is guided by the leg 3 by means of shoes 15a-1d' in between the cylinders 8a-8d'. The lower ring 18 is arranged between the maindeck and the lowest position of yokes 7a-7d.

So far the jacking systems are described above, the cylinders are delivering the jacking force in the pushing mode, when carrying the platform. Normally this mode is most advantageous because the cylinder provides more force at the same hydraulic pressure than in the pulling mode.

However, in some arrangements, there might be a good reason to apply the pulling mode instead. The invention covers both the pushing mode and the pulling mode.

In any embodiment of the invention as described before numerous adaptations and modifications are possible. Although four yokes 7 per leg 3 are described above, in a similar fashion three yokes could be applied. In the case that three yokes are applied, each time two yokes are load bearing whereas the third yoke is in its returning motion. In this case again the idle sides of the load bearing cylinders can be connected to the returning side of the returning cylinder, forcing this to return to its original position.

Also more than four yokes can be applied in a similar alternating sequence.

Within the hydraulic piping system, each cylinder assembly is dedicated to an individual yoke, which can be performing a repetitive or alternating sequence. In such a hydraulic system, rotary hydraulic valves can be applied e.g. for both the working piston side and the idle piston side of the cylinders.

Throughout the description the actuators are described as hydraulic cylinders. These actuators can also be other mechanical, electrical or electromechanical actuators, such as e.g. linear motors.

These and other adaptations and modifications are possible without departing from the spirit and scope of the invention as defined in the claims.

Claims

1. Jacking system for a leg of a jack-up platform, comprising
- at least three independent yokes, each yoke is connected to a jack-up structure by at least one vertically arranged double acting actuator and is equipped with a leg engaging mechanism such as a horizontally arranged movable locking pin, which is configured to engage or to disengage with a hole of the jack-up leg, in order to transfer a load from the jack-up platform to the leg, including a controller configured to operate the yokes in a way that the leg is moved by all the at least three yokes in an alternating mode, such that at any moment in time during operation all but one of the at least three yokes take the load via the associated engaging mechanism, while the remaining yoke of the at least three yokes makes a return stroke with its engagement mechanism in a disengaged position.

2. Jacking system according to claim 1, wherein the alternating mode involves that a yoke of the at least three yokes that has made a return stroke, while the other yokes are load bearing is controlled such that a next return stroke of that yoke occurs only after each of the other yokes also have made a return stroke.

3. Jacking system according to any of the preceding claims, wherein all engagement mechanisms are engaged when the jacking system is not in operating mode.

4. Jacking system according to any of the preceding claims, wherein the actuators are operated in a way that each leg can be moved at a constant speed.

5. Jacking system according to any of the preceding claims, wherein the actuators are chosen from the group of air cylinders, electric actuators or hydraulic cylinders.

6. Jacking system according to any of the preceding claims, where the return stroke of the at least one actuator of the remaining yoke is activated by the outflow of the actuators of the yokes that are load bearing.

7. Jacking system according to any of the preceding claims, wherein the holes in the leg are arranged in a helical or spiral form around the leg.

8. Method for moving a leg of a jack up platform comprising the steps of:

- providing a jacking system according to any of claims 1-7;
- associating the jacking system with a leg of a jack up platform;
- disengaging an engagement mechanism of a remaining yoke from a hole of the leg while maintaining the engagement of the yokes that are load bearing;
- actuating the actuators of the engaged yokes, while returning the first disengaged yoke in its original position;
- re-engaging the first yoke and disengaging a second yoke
- repeating the above steps for each consecutive yoke, one at a time, thus moving the leg in an upright direction.