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BRACE ASSEMBLY FOR TRUSS LEGS OF OFFSHORE STRUCTURES

BACKGROUND OF THE INVENTION

The present invention relates to offshore structures, and more particularly, to a brace assembly for a truss leg.

Leg-supported offshore structures are extensively used for mineral exploration and production. Convention truss legs comprise a system of horizontal and diagonal braces. The legs are raised or lowered by an elevating system, for instance a self-elevating jacking system that contains racks and pinions. In a typical system using triangular truss legs, there are a total of nine jacking assemblies, three assemblies per leg. One jacking assembly is mounted at each chord of the leg. Each jacking assembly unit has four to six pinions, which are house and supported on bearings.

A series of guide plates is installed above and below the jacking mechanism. The guide system consists of upper guide plates, middle guide plates and lower wear plates. Gaps between guide plates and rack are pre-determined to ensure smooth transition in raising and lowering the legs. Initially, when the pinions support the entire weight of the hull unit, the differential loads on the pinions cause a vertical moment couple during the jacking up process. Under environmental loads, the unit tilts and the rack teeth react against the guide plates. The guide plates act as horizontal restraint for the drilling unit as it deflects under harsh environmental conditions. This generates a reaction on the guide plates along the chord and indirectly on the horizontal and diagonal braces. The differential loads in the guide plates cause a horizontal moment couple to be developed.

As the jacking up process continues, the loads are increasingly transferred from a vertical to a horizontal moment couple. The development of the horizontal couple cause the leg between the upper and lower guide plates to sustain a large bending moment. Thus the braces between the upper and lower guide plates develop compressive and tensile forces. As the truss legs are composed of horizontal and diagonal braces, the



braces tend to fail under compressive loads, which is built up due to the horizontal moment couple. High compressive loads are undesirable as they result in buckling of the braces under severe environmental conditions. For example, when a rig suffers a severe punch through situation or when the spud can at the base of the unit slides into old footings. This guide assembly is not efficient, as the generated high compressive loads located mainly between the upper and lower edge plates. This constitutes a local failure within the system. A premature local buckling of the brace assembly eventually occurs.

The capacity of the drilling unit to maintain stability and strength during working conditions is determined by the extent the braces are subjected to the loads through the guide plates. Due to the constraints in terms of weight and drag, it is not feasible to design the braces with heavy tubular sections. In conventional designs, the braces are strengthened by using a larger diameter tubular or a thick-wall tubular. With such designs, it is difficult and often costly to improve the strength of the braces due to the high cost involved in replacing all brace segments. To replace the brace members, the rig would have to be towed to a shipyard, where the bent section of the leg has to be removed and replaced. The expense associated with work stoppage as well as replacement of the damaged section and retrofitting the leg, plus the required manpower is often very high.

Since the braces are the weak link in the overall leg structure, the present invention contemplates elimination of drawbacks associated with prior designs and provision of a method of improving the capacity of the braces to handle high buckling loads.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved design of a brace assembly for a support leg of an offshore structure.

It is another object of the present invention to provide a method of retrofitting existing brace assemblies in situ.

These and other objects of the invention are achieved through a provision of a reinforcing sleeve means for positioning over a pre-determined portion of a brace member and for increasing structural resistance of the brace member to horizontal moments. The reinforcing sleeve means is mounted and secured in a surrounding relationship about the exterior of the brace member. The thickness of the reinforcing sleeve means depends on the particular requirements of the load bearing capacity that must be achieved at the particular location of the overall structure.

The reinforcing sleeve may be made of a plurality of materials, preferably non-corrosive materials. One of the suitable materials is steel, another may be a composite fiber material. In the case of the composite fiber materials, the reinforcing sleeve is adhesively secured in multiple layers over the portion of the brace member where reinforcement is particularly desirable. The reinforcing sleeve may be installed on shore, during construction of the rig, or in situ by a simple retrofit process of existing brace assemblies.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the drawings, Figure 1 is an outboard profile of a jack-up unit of the present invention with truss legs.

Figure 2 is a plan view showing position of the legs in relation to the platform layout and schematically illustrating jacking assemblies.

Figure 3 is a detail view of segment of a brace assembly of the support leg structure in accordance with the present invention.

Figure 4 is a cross-sectional view of a portion of a brace member with a reinforcing sleeve welded to the exterior of a brace member.

Figure 5 is a detail view illustrating positioning of the reinforcing sleeve on a tubular of a brace member.

Figure 6 is a cross-sectional view of a portion of a brace member wherein the reinforcing sleeve is formed from a composite material.

Figure 7 is a detail view illustrating position of the reinforcing sleeve made of a composite material on a tubular of a brace member.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made to the following detailed description, taken in conjunction with the accompanying drawings, wherein like parts are designated by like numerals.

Figure 1 shows a self-elevating jack-up unit. The jack-up unit is a mobile offshore structure that is used for mineral exploration and production. A typical jack-up unit is provided with a plurality of truss legs 12, which extend through openings in a floatable hull 14 of the jack-up unit. Although any number of legs may be used to support the hull 14, for illustration purposes, the jack-up rig shown in Figure 1 has three such legs 12. The legs 12 are formed by a system of horizontal and diagonal braces.

As the legs 12 are "jacked," the hull 14 is elevated above an anticipated wave action to support the offshore exploration and/or production operations. Conventional offshore structures, such as the jack-up unit, are equipped with a derrick 16 mounted on the hull 14. The derrick 16 may be also mounted on a cantilever structure 18, which extends outwardly from the hull 14, as shown in Figure 1.

The derrick 16 may be positioned for a limited lateral movement to accommodate well drilling in a plurality of locations without changing the position of the legs 12. The jack-up unit may be also provided with auxiliary equipment, such as cranes 20, pipe racks, heliport, crew living quarters, etc.

Each leg 12 is provided with the jacking assemblies 30 for moving the leg vertically with respect to the hull 14. The jack assemblies 30 are retained against vertical displacement by the hull 14. The legs 12 move from a raised position, when the jack-up unit is in transit and the legs 12 are supported by the hull 14, to a lowered position, when the legs 12 support the hull 14. The lowered position is illustrated in Figure 1. Each leg

12 may be provided with a spud can 34 for bearing against an ocean floor and for supporting the jack-up unit.

Turning now to Figure 3, a portion of a leg truss structure is shown in more detail. A segment of the brace assembly is defined by an upper horizontal brace member 22, a lower horizontal member 24, a first vertical chord member 26 and a second vertical chord member 28. Extending between the horizontal and vertical brace and chord members is a plurality of angular, or diagonal brace members 36, 38, 40 and 42. The first and the second diagonals 36 and 38 extend from the vertical chords 26 and 28 upwardly to the center of the upper horizontal brace member 22. The second and the fourth diagonals 40 and 42 extend from the vertical chord members 26 and 28 downwardly to meet at the center of the lower horizontal brace member 24.

Middle portions of the horizontal and diagonal braces were shown to be prone to bending or buckling. To reinforce the critical areas of the brace members, the present invention provides for the use of reinforcing sleeves that are mounted in an enveloping relationship on the middle portions of the horizontal and diagonal braces. A reinforcing sleeve 52 is mounted about the central portion of the upper horizontal brace member 22 spanning between one clear span, node to node.

A reinforcing sleeve 54 is mounted about the middle portion of the first diagonal brace member 36; a reinforcing sleeve 56 is mounted about the middle portion of the second diagonal brace member 38; a reinforcing sleeve 58 is mounted about the middle portion of the third diagonal brace member 40 a reinforcing sleeve 60 is mounted about the middle portion of the fourth diagonal brace member 42.

A reinforcing sleeve 62 is mounted about the central portion of the lower horizontal brace member 24, similarly to the sleeve 52 spanning between one clear span, node to node.

The reinforcing sleeves 52, 54, 56, 58, 60, and 62 may be made from a variety of non-corrosive, structurally strong materials. For instance, rolled steel or composite fiber material may be employed for forming the reinforcing sleeves. Figures 4 and 5 illustrate position of a rolled steel sleeve 54 on the first diagonal brace member 36. As can be seen in the drawings, the sleeve 54 covers a portion of the elongated brace member 36. The sleeve 54 is made of two semicircular sections 55, 57 joined together and welded at weld points 66, 68. The interior diameter of the sleeve 54 is equal to or slightly greater than the exterior diameter of the brace member 36. The thickness and length of the sleeve 54 will vary depending on the particular buckling capacity of the respective portion of the truss structure. The physical dimensions of the reinforcing sleeve will also depend on the length over the diameter ratio of the brace member. The same design may be used for the horizontal and diagonal braces.

Alternatively, the reinforcing sleeve may be made of a composite fiber material. Figures 6 and 7 illustrate position of such a sleeve 56 on the brace member 38. To position the composite material on a section of the brace member 38, the exterior surface of the brace member is properly prepared as for application of an adhesive. Then the designated length of the brace member 38 is coated with a bonding agent. The material of the sleeve, such as finely woven fabric, is wrapped around the designated area in multiple layers. For most applications, it is believed that 5 – 10 layers of the material should be sufficient, depending on the strength required.

The composite material consists of fibers that are laid at different orientation at different layers to obtain the maximum effect of the fiber strength in the bending direction. The bonding material may be a resin that cures in a relatively short period of time. The shrinkage of the resin, when cured ensures that the reinforcing sleeve becomes bonded into the steel surface. The composite material is much lighter than steel and has the added advantage of low drag and thickness. The stiffness at the middle section of the brace members depends on the number of layers applied and can be configured to achieve the required stiffness. Of course, other materials may be successfully used for forming the reinforcing sleeves. Steel and composite fiber are merely examples of suitable

compositions that can be used for the purpose of providing enhanced structural strength to the portions of the brace members subject to the most stresses.

The introduction of the reinforcing sleeves significantly improves the overall efficiency of the rig by strengthening the bracing members of the leg assemblies. The increase in the resistance to buckling reduces the tendency of the brace to fail at the most stressful initial condition. The reinforcing sleeves may be positioned on the brace members during construction of the rig at the shipyard or applied to the existing structure by retrofitting the trusses in situ. The amount of steel used, when steel reinforcing sleeves are contemplated, is much lower than would be required for a full replacement of the bracing members. Additional advantage of retrofitting the existing leg structure in situ is that the normal drilling operations can continue while retrofitting takes place.

Furthermore, the rig structure configuration remains much the same. Only minor changes are made in the design at relatively low cost of the material and the installation. The increased efficiency and load sharing capacity between the brace members outweigh the added cost of the reinforcing sleeves. The current capacity of the leg can be made more robust by an effective use of the reinforcing sleeves installed at strategic locations to allow the leg to take on a higher buckling load.

It is envisioned that the reinforcing sleeve and method of its installation may be used for reinforcing other brace members and structural elements subject to horizontal moment tending to bend the brace member. This design may find its application in construction, mechanical engineering and other industries where enhanced structural stability of a component is required.

Many changes and modifications may be made in the design of the present invention without departing from the spirit thereof. We, therefore, pray that our rights to the present invention be limited only by the scope of the appended claims.

We Claim:

1. A brace assembly for a truss leg, comprising:
an elongated tubular member; and
a reinforcing sleeve positioned about exterior of a pre-determined portion of the tubular member, said sleeve substantially conforming to the exterior configuration of the tubular member.
2. The apparatus of Claim 1, wherein said sleeve is formed from a non-corrosive material.
3. The apparatus of Claim 2, wherein said non-corrosive material is steel.
4. The apparatus of Claim 2, wherein reinforcing sleeve is welded to the tubular member.
5. The apparatus of Claim 2, wherein said non-corrosive material is composite fiber material.
6. The apparatus of Claim 5, wherein said reinforcing sleeve is adhesively secured on said tubular member.
7. The apparatus of Claim 5, wherein said reinforcing sleeve comprises a plurality of layers of the composite fiber material wrapped around exterior of the pre-determined portion of the tubular member.
8. A brace assembly for a truss leg of an offshore structure having vertically extending leg chords, the brace assembly comprising:

a first horizontal member extending in a transverse relationship between a first leg chord and a second parallel leg chord;

a second horizontal member extending in a transverse relationship between the first leg chord and the second parallel leg chord below said first horizontal member;

a plurality of angular brace members extending between the first horizontal brace member and the second horizontal brace member; and

wherein each of said first horizontal brace member, said second horizontal brace member, said plurality of angular brace members is provided with a reinforcing sleeve mounted about exterior surfaces thereof.
9. The apparatus of Claim 8, wherein each of said reinforcing sleeves covers at least a portion of an outer periphery of a corresponding brace member.

10. The apparatus of Claim 8, wherein each of said reinforcing sleeves is formed from a non-corrosive material.
11. The apparatus of Claim 10, wherein said non-corrosive material is steel.
12. The apparatus of Claim 10, wherein said non-corrosive material is composite fiber material positioned in a plurality of layers about a pre-determined portion of a respective brace member.
13. The apparatus of Claim 12, wherein said composite fiber material is adhesively secured to the pre-determined portion of a respective brace member.
14. A method of reinforcing a brace member of a truss leg, comprising the steps of:

 providing a reinforcing sleeve means for positioning over a pre-determined portion of the brace member;

 positioning said reinforcing sleeve means in a surrounding relationship over the pre-determined portion of the brace member, thereby increasing resistance of the brace member to bending loads.
15. The method of Claim 14, wherein said reinforcing sleeve means is formed from a non-corrosive material.
16. The method of Claim 15, wherein said non-corrosive material is steel.
17. The method of Claim 15, wherein said non-corrosive material is composite fiber material.
18. The method of Claim 14, wherein said reinforcing sleeve means comprises a hollow member having an interior diameter slightly greater than an exterior periphery of the pre-determined portion of the brace member.