

APPARATUS FOR CONNECTING TO A RISER

FIELD OF THE INVENTION

The present invention relates to an apparatus for connecting to a riser. In particular, the present invention relates to a bell mouth that can be used for
5 multiple types of risers.

BACKGROUND ART

The following discussion of the background to the invention is intended to facilitate an understanding of the present invention only. It should be appreciated that the discussion is not an acknowledgement or admission that
10 any of the material referred to was published, known or part of the common general knowledge of the person skilled in the art in any jurisdiction as at the priority date of the invention.

In deep water oil and gas exploration, flexible risers are crucial in fluid flow ducts for offshore engineering. A spread mooring floating production storage and
15 offloading (FPSO) vessel typically has a riser balcony where equipment is installed, and on the riser balcony, equipment is installed to pull the risers from the seabed/buoy and connect it to the FPSO, and fluid such as oil/gas will flow through the riser and into the FPSO for further production and storage. Beneath the balcony, bell mouths/riser I-tubes, which provide riser hang-off so that risers
20 can be connected to a flowline, are installed.

Risers can be heavy structures. Due to ocean currents, risers are susceptible to drag forces and therefore bending stresses. As such, relatively heavy risers are used so that they can withstand the bending stresses. A bell mouth or fixed support for connecting to a riser should be strong enough to withstand the
25 weight of the heavy riser, particularly when transporting a gas or liquid.

A number of systems have been developed for riser hang-offs to link flexible risers to the FPSO and an example is shown in Figure 1 from US 6,631,745. This system has a flexible joint 020A hung at the bell mouth 010A which is permanently connected to support 002 that sits on the hull 001. Another

example is US 4,281,614, which makes use of a ball joint apparatus to couple between the upper end of the riser and the floating structure to define the boundaries of a path of fluid flow between the riser and the floating structure.

5 One problem is that the angular allowance of existing systems depend on the flexible joint or ball joint capacity as the angle of the flexible joint towards the bell mouth or fixed support cannot be changed. Typically, the angle of each bell mouth or fixed support is calculated and designed for a specific line of riser, and once designed and fabricated, it cannot be used for another riser or another location without having to refabricate the bell mouth or fixed support.

10 The other issue is that a typical system would require flame cutting and welding in order to effect a change of risers, which would lead to a change in the riser pull up angle as well. Because of this, a previous bell mouth utilized for a riser cannot be used for the new riser, and the previous bell mouth may be cut off depending on circumstances, and a new bell mouth with an appropriate riser
15 angle needs to be welded. It is therefore to be appreciated that the orientation of risers can change as the end position of the riser on the seabed module changes.

An example of a bell mouth that is able to accommodate different riser lines is provided in Singapore patent no. 10201601701Y, which makes use of at least
20 one actuator to accommodate the riser line. However, the locking capacity of the bell mouth is low. As such, this affects the ability of the bell mouth to withstand the weight of the heavy riser, particularly when transporting a gas or liquid.

The present invention seeks to provide an apparatus that alleviates the above
25 mentioned drawbacks at least in part.

SUMMARY OF THE INVENTION

Throughout this document, unless otherwise indicated to the contrary, the terms “comprising”, “consisting of”, and the like, are to be construed as non-exhaustive, or in other words, as meaning “including, but not limited to”.

As used herein, the terms “bell mouth” and “bell mouth assembly” are used interchangeably, and will be understood by a skilled person to refer to an apparatus for connecting to a riser.

As used herein, the term “orientation” may include the position of the bell mouth
5 as determined by at least two variables comprising a top angle “a” and the azimuth angle “b” of the bell mouth.

As used herein, the term “umbilical line” will have the ordinary meaning in the art and will be understood by a skilled person to refer to a cable and/or hose that supplies consumables, such as a hydraulic power supply, an electrical
10 power supply, an electrical signal, a fiber-optic signal, a chemical supply, a gas supply or a mixture thereof, to an apparatus.

The above and other problems are solved and an improvement in the art is made by an apparatus in accordance with the present invention. A first advantage of the apparatus in accordance with the present invention is that the
15 bell mouth has a significantly better locking capacity compared to the bell mouth of Singapore patent no. 10201601701Y. In addition, the present invention has a comparable locking capacity to other prior art bell mouths. In particular, the bell mouth of the present invention comprises a bell mouth body for allowing the riser to pass through and an upper cover for locking the bell mouth body to
20 an orientation; wherein the bell mouth body comprises a ring shaped and dimensioned to be disposed around an outer surface of the bell mouth body and wherein the upper cover is engageable with the ring. As such, the upper cover and the ring of the bell mouth body are arranged to interact with one another to achieve the locking of the bell mouth at the orientation and is strong
25 enough to withstand a load, such as but not limited to, a riser. A second advantage of the apparatus in accordance with the present invention is that the bell mouth angles (top angle and azimuth angle) can be changed by replacement of the bell mouth stoppers, preferably profiled bell mouth stoppers, thereby achieving flexibility in adjusting the bell mouth angles. In particular, the
30 profile of the bell mouth stoppers are profiled in such a way that the bell mouth body can be locked to a desired top angle “a” and a desired azimuth angle “b”

(see Figure 2A and 2B). Consequently, this enables the same bell mouth to be able to engage different risers (such as but not limited to, a flexible riser or steel lazy wave riser) or even operate at different operation sites without having to replace the whole bell mouth. A third advantage of the apparatus in accordance with the present invention is that it dispenses with the need for hot processes such as flame cutting and welding when the connected riser needs to be changed to, for example, another type of riser. As such, the installation of the apparatus in accordance with the present invention may be less risky because there are risks associated with flame cutting and welding (such as fire accidents). In addition, the installation of the apparatus in accordance with the present invention may be fast and convenient compared to an installation process that requires hot processes such as flame cutting and welding. A fourth advantage of the apparatus in accordance with the present invention is that it provides protection for umbilical lines and flexible risers. Consequently, the apparatus in accordance with the present invention is able to achieve a combination of the afore-mentioned advantages.

In an aspect, there is provided an apparatus for connecting to a riser, the apparatus comprising a bell mouth body for allowing the riser to pass therethrough, at least one set of bell mouth stoppers for adjusting an orientation of the bell mouth body and an upper cover for locking the bell mouth body at the orientation; wherein the bell mouth body comprises a ring configured around an outer surface of the bell mouth body and wherein the at least one set of bell mouth stoppers is configured to engage the upper cover with the ring.

Preferably, the apparatus further comprises a lower cover for covering the ring.

Preferably, the ring comprises an upper surface and a lower surface, and wherein the at least one set of bell mouth stoppers engages with the upper surface and the lower surface of the ring.

Preferably, the upper cover comprises a first half and a second half, wherein each half comprises a set of rods spaced apart from each other via a gap, and wherein the at least one set of bell mouth stoppers engages the gap to produce an interlock.

Preferably, the at least one set of bell mouth stoppers comprises upper bell mouth stoppers and lower bell mouth stoppers.

Preferably, the upper bell mouth stoppers comprises at least one bell mouth stopper, each bell mouth stopper comprising a first portion and a second
5 portion, wherein the height of the first portion and the height of the second portion changes from a first end to a second end of the upper bell mouth stoppers.

Preferably, the lower bell mouth stoppers comprises at least one bell mouth stopper, each bell mouth stopper comprising a first portion and a second
10 portion, wherein the height of the first portion and the height of the second portion changes from a first end to a second end of the lower bell mouth stoppers.

Preferably, the apparatus further comprises a bell mouth outer support base.

Preferably, the bell mouth outer support base comprises an inner wall and a set
15 of bell mouth stopper slots for receiving at least one bell mouth stopper, wherein the set of bell mouth stopper slots are positioned on the inner wall of the bell mouth outer support base.

Preferably, the inner wall of the bell mouth outer support base is spherical in shape and wherein the ring comprises a spherical outer surface engageable
20 with the inner wall of the bell mouth outer support base.

Preferably, the at least one set of bell mouth stoppers is made of a lightweight and high-strength material.

Preferably, the light weight and high strength material is stainless steel, ASTM-A514, EN10029 or S690.

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BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 shows existing bell mouth interfaces for a steel catenary riser used for FPSOs;

Fig. 2A is an enlarged view of an apparatus in accordance with an embodiment of the invention, showing the adjustable top angle without a riser connected;

5 Fig. 2B is a top view of an apparatus in accordance with an embodiment of the invention, showing the adjustable azimuth angle without a riser connected;

Fig. 3A is a cross-sectional view of an apparatus in accordance with an embodiment of the invention as viewed from the A-A cross section of Fig. 2B;

10 Fig. 3B is another cross-sectional view of an apparatus in accordance with an embodiment of the invention;

Fig. 4 is an exploded view of an apparatus in accordance with an embodiment of the invention;

Fig. 5 is a perspective view of the bell mouth outer support in accordance with an embodiment of the invention;

15 Fig. 6A is an enlarged view of the bell mouth assembly in accordance with an embodiment of the invention, showing the bell mouth body and the bell mouth stoppers; Fig. 6B is another enlarged view of the bell mouth assembly in accordance with an embodiment of the invention, showing the bell mouth body and the bell mouth stoppers;

20 Fig. 7 is a perspective view of the bell mouth stoppers in accordance with an embodiment of the invention;

Fig. 8 is a perspective view of the bell mouth body in accordance with an embodiment of the invention;

25 Fig. 9 is another perspective view of the bell mouth body in accordance with an embodiment of the invention, showing an installation frame connected to the bell mouth outer support;

Fig. 10A illustrates the three conditions (a, b, c) that were considered for an ANSYS™ analysis of a bell mouth that is in accordance with an embodiment of the invention;

Fig. 10B is a cross-sectional view of the welded structure of the bell mouth that
5 was used for the ANSYS™ analysis;

Fig. 10C is a cross-sectional view of the bell mouth outer support base that was used for the ANSYS™ analysis, wherein the dimensions of the bell mouth outer support base are indicated;

Fig. 10D to 10F relate to condition a, and illustrate the ANSYS™ results of
10 stress contour plot for the spherical outer surface of the ring of the bell mouth body engaging with an inner wall of the bell mouth outer support base;

Fig. 10G and 10H relate to condition a, and illustrate the ANSYS™ results of stress contour plot for the bell mouth outer support base;

Fig. 10I relates to condition a, and illustrates the ANSYS™ results of stress
15 contour plot for a set of bell mouth stoppers in accordance with an embodiment of the invention;

Fig. 10J relates to condition a, and illustrates the ANSYS™ results of stress contour plot for the upper bell mouth stoppers of Fig. 10I;

Fig. 10K relates to condition a, and illustrates the ANSYS™ results of stress
20 contour plot for an upper bellmouth cover

Fig. 10L relates to condition a, and illustrates the ANSYS™ results of stress contour plot for the spherical outer surface of the ring of the bell mouth body;

Fig. 10M to 10O relate to condition b, and illustrate the ANSYS™ results of
25 stress contour plot for the spherical outer surface of the ring of the bell mouth body engaging with an inner wall of the bell mouth outer support base;

Fig. 10P relates to condition b, and illustrates the ANSYS™ results of stress contour plot for the bell mouth outer support base;

Fig. 10Q relates to condition b, and illustrates the ANSYS™ results of stress contour plot for a set of bell mouth stoppers in accordance with an embodiment of the invention;

5 Fig. 10R relates to condition b, and illustrates the ANSYS™ results of stress contour plot for both upper bellmouth covers;

Fig. 10S relates to condition b, and illustrates the ANSYS™ results of stress contour plot for the spherical outer surface of the ring of the bell mouth body;

10 Fig. 10T to 10V relate to condition c, and illustrate the ANSYS™ results of stress contour plot for the spherical outer surface of the ring of the bell mouth body engaging with an inner wall of the bell mouth outer support base;

Fig. 10W and 10X relate to condition c, and illustrate the ANSYS™ results of stress contour plot for the bell mouth outer support base;

15 Fig. 10Y and 10Z relate to condition c, and illustrate the ANSYS™ results of stress contour plot for a set of bell mouth stoppers in accordance with an embodiment of the invention;

Fig. 11A relates to condition c, and illustrates the ANSYS™ results of stress contour plot for an upper bellmouth cover; and

Fig. 11B relates to condition c, and illustrates the ANSYS™ results of the spherical outer surface of the ring of the bell mouth body;

20 Other arrangements of the invention are possible and, consequently, the accompanying drawings are not to be understood as superseding the generality of the preceding description of the invention.

DETAILED DESCRIPTION OF THE INVENTION

25 Particular embodiments of the present invention will now be described with reference to the accompanying drawings. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to

limit the scope of the present invention. Additionally, unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs.

5 In accordance with an embodiment of the present invention, there is an apparatus for connecting to a riser, bell mouth assembly 004, disclosed as shown in Figs. 2A and 2B to 9. One set of bell mouth stoppers 005 for setting both the top angle "a" and the azimuth angle "b" are shown in Figs. 2A and 2B to 9. However, it is appreciable that there may be more than one set of bell
10 mouth stoppers 005, such that at least one set of bell mouth stoppers 005 may be used for setting the orientation of the bell mouth, particularly the bell mouth body 410. For consistency, the same reference numerals will be used for the same parts across the various figures. A bell mouth balcony 002 is shown connected to the side or the hull 001 of the FPSO. In various embodiments, the
15 bell mouth balcony 002 may be located close to the keel and underwater at the starboard side or the port side, near midship of the FPSO. The bell mouth outer support base 003 (also referred to as "housing") can be connected to the bell mouth balcony 002 by using studs and nuts or welding or any other methods for affixing two structures, even a combination of these methods.

20 In various embodiments and as shown in Figs. 3A, 3B (collectively referred to as "Fig. 3"), 4 and 8, the bell mouth assembly 004 comprises a bell mouth body 410 for allowing a riser to pass through, at least one set of bell mouth stoppers 005 for setting an orientation of the bell mouth body 410 and an upper cover 320 (also referred to as "top cover") for locking the bell mouth body 410 at the
25 set orientation, wherein the bell mouth body 410 comprises a ring 411 (also referred to as "ball") configured around an outer surface of the bell mouth body 410, and wherein the at least one set of bell mouth stoppers 005 is configured to engage the upper cover 320 with the ring 411. In other words, the upper cover 320 is engageable with the ring 411 via the bell mouth stoppers 005. As
30 such, the bell mouth body 410 is locked in a particular orientation.

Advantageously, this leads to a significantly better locking capacity compared to the bell mouth of Singapore patent no. 10201601701Y.

In various embodiments, the ring 411 comprises an upper surface 412 and a lower surface 413, for contacting with an inner wall 301 of the bell mouth outer support base 003. In various embodiments, the outer surface of the ring 411 is a spherical surface and the inner wall 301 of the bell mouth outer support base 003 is a spherical wall so that the ring 411 can contact or interact with the inner wall 301 in a fitting manner. Advantageously, this results in a bell mouth with better locking capacity. The ring 411 can be connected to the bell mouth body 410 by welding or any other methods for affixing two structures, even a combination of these methods.

In various embodiments and as shown in Figs. 2A, 2B and 3, the pivotable bell mouth assembly 004 is fitted inside the bell mouth outer support base 003 by the upper cover 320 secured on an upper end of the bell mouth outer support base 003. In various embodiments, the bell mouth assembly 004 further comprises a lower cover 310 (also referred to as "bottom cover") for covering the ring 411. Advantageously, the lower cover 310 acts as a cover or seal to protect at least a portion of the ring 411 from damage. The upper cover 320 and the lower cover 310 are detachably secured to the bell mouth outer support base 003 using studs and nuts 330 or any other methods for affixing two structures, even a combination of these methods.

In various embodiments and as shown in Fig. 4, the upper cover 320 may comprise a first half 320a and a second half 320b, wherein each half 320a, 320b comprises a set of rods 324 mounted on a semi-circular holder using studs and nuts 330. The set of rods 324 are spaced apart from each other at regular intervals, thereby leading to the formation of a gap between any two rods 324. Advantageously, the upper cover 320 is configured to engage at least one bell mouth stoppers 005 via the gap between any two rods 324 to produce an interlock, thereby locking the orientation of the bell mouth and resulting in a bell mouth that has a better locking capacity compared to the bell mouth of Singapore patent no. 10201601701Y. As such, the at least one bell mouth

stoppers 005 is fixed in position and does not move outwards or deform when the bell mouth is subjected to a load.

In various embodiments and as shown in Figs. 3, 4, 6 (comprising Fig. 6A and Fig. 6B) and 7, the bell mouth assembly 004 further comprises at least one set of bell mouth stoppers 005 engageable with the ring 411 of the bell mouth body 410. Specifically, the at least one set of bell mouth stoppers 005 is configured to engage an upper surface 412 and a lower surface 413 of the ring 411. Advantageously, the bell mouth stoppers 005 allow flexibility in setting the top angle "a" and the azimuth angle "b" of the pivotable bell mouth assembly 004 because the bell mouth stoppers 005 can be fabricated with different parameters associated with the bell mouth stoppers 005, such as but not limited to, height of the bell mouth stoppers 005 and one or more profiles of the bell mouth stoppers 005). As such, the orientation of the bell mouth body 410 may be changed by replacing the bell mouth stoppers 005. In addition, without the at least one set of bell mouth stoppers 005, the bell mouth body 410 would be free to rotate to any top angle "a" from -15 degrees to +15 degrees or any azimuth angle "b" from -25 degrees to +25 degrees. In various embodiments, the at least one set of bell mouth stoppers 005 assists the upper cover 320 in fitting the pivotable bell mouth assembly 004 inside the bell mouth outer support base 003. In various embodiments, the bell mouth stoppers 005 are press-locked inside the bell mouth housing structure (comprising the bell mouth outer support base 003 and the ring 411) by the upper cover 320, which acts as a fastening means. The bell mouth stoppers 005 are press-locked due to engaging of the upper cover 320 with the at least one bell mouth stoppers 005 via the gap between any two rods 324 to produce an interlock, thereby locking the orientation of the bell mouth and resulting in a bell mouth that has a better locking capacity compared to the bell mouth of Singapore patent no. 10201601701Y.

In various embodiments, the bell mouth assembly 004 comprises one set of bell mouth stoppers 005 in the form of upper bell mouth stoppers 510 (not shown). In various embodiments, the at least one set of bell mouth stoppers

005 comprises upper bell mouth stoppers 510 and lower bell mouth stoppers 520. Advantageously, the upper bell mouth stoppers 510 and the lower bell mouth stoppers 520 will lock the bell mouth body 410 at a specific top angle “a” and a specific azimuth angle “b”. In addition, the upper bell mouth stoppers 510
5 and the lower bell mouth stoppers 520 may work together with the upper cover 320 to provide a better locking capacity compared to the bell mouth of Singapore patent no. 10201601701Y. In the absence of the upper cover 320, the bell mouth assembly 004 is not strong enough to withstand a load. Each set of bell mouth stoppers 510, 520 comprises at least one bell mouth stopper.

10 The top angle “a” and the azimuth angle “b” of the pivotable bell mouth assembly 004 can be changed by replacing bell mouth stoppers 005. In other words, either or both the top angle “a” and the azimuth angle “b” can be changed by replacing the upper bell mouth stoppers 510 and/or lower bell mouth stoppers 520. As such, there is flexibility in changing the top angle “a”
15 and the azimuth angle “b”. In another embodiment, replacement of the bell mouth stoppers 005 is done before locking of the bell mouth assembly 004 using the upper cover 320. Optionally, the bell mouth assembly 004 is covered using the lower cover 310.

In various embodiments, the adjustment of the top angle and the azimuth angle
20 may be carried out anywhere and anytime. For instance, the top angle and the azimuth angle may be adjusted on-site after the bell mouth assembly 004 has operated for a period of time, such as but not limited to a few years, and replacement of the riser is necessary (such as, replacing of a flexible riser to a steel catenary riser). This can be achieved because the top angle “a” and the
25 azimuth angle “b” of the pivotable bell mouth assembly 004 can be changed simply by replacing bell mouth stoppers 005.

In various embodiments, the adjustment of the top angle and the azimuth angle is carried out, for instance, on a main deck of a vessel so that the entire assembly may be lifted up and the existing set of bell mouth stoppers 005 for a
30 first specific top angle and azimuth angle may be replaced by another set of bell mouth stoppers 005 for a second specific top angle and azimuth angle,

wherein the second specific top angle and azimuth angle are different from the first specific top angle and azimuth angle. As such, the orientation of the bell mouth body 410 may be changed or adjusted by replacing the bell mouth stoppers 005.

5 The orientation of the bell mouth body 410 depends on the profile of the bell mouth stoppers 005. In particular, the upper bell mouth stoppers 510 and the lower bell mouth stoppers 520 are profiled in such a way that the bell mouth body 410 can be locked to a desired top angle "a" and a desired azimuth angle "b". In various embodiments and as illustrated in Fig. 7, the upper bell mouth
10 stoppers 510 comprises a set of bell mouth stoppers, each bell mouth stopper comprising a first portion having a height H_1 and a second portion having a height H_2 , the bell mouth stoppers positioned adjacent to one another to form a first end 510a and a second end 510b. The bell mouth stoppers of the upper bell mouth stoppers 510 are configured such that the height H_1 of the first
15 portion and the height H_2 of the second portion changes from the first end 510a to the second end 510b of the upper bell mouth stoppers 510. For instance, the height H_1 of the bell mouth stopper closest to the first end 510a may be smaller than the height H_1 of the bell mouth stopper adjacent to it. Accordingly, there may be an increase in the height H_1 of each successive bell mouth stopper until
20 the middle of the set of bell mouth stoppers making up the upper bell mouth stoppers 510 is reached. Subsequently, there is a decrease in the height H_1 of each successive bell mouth stopper until the second end 510b of the upper bell mouth stoppers 510 is reached. The bell mouth stoppers of the upper bell mouth stoppers 510 are aligned in a successive manner at a regular interval,
25 which leads to the formation of a locking surface 511 for engaging with the upper surface 412 of the ring 411 and the formation of a lower surface 512 for resting on a bell mouth support bearing surface 303 of the bell mouth outer support base 003. In a preferred embodiment, the number of upper bell mouth stoppers 510 is twelve (12). In general, a smaller number of upper bell mouth
30 stoppers 510 is preferred and the number of upper bell mouth stoppers 510 used should be sufficient to withstand a particular load at a particular orientation and is dependent on the load that the bell mouth has to withstand.

In various embodiments and as illustrated in Fig. 7, the lower bell mouth stoppers 520 comprises a set of bell mouth stoppers, each bell mouth stopper comprising a first portion having a height H_1' and a second portion having a height H_2' , the bell mouth stoppers positioned adjacent to one another to form a first end 520a and a second end 520b. The bell mouth stoppers of the lower bell mouth stoppers 520 are configured such that the height H_1' of the first portion and the height H_2' of the second portion changes from the first end 520a to the second end 520b of the lower bell mouth stoppers 520. For instance, the height H_1' of the bell mouth stopper closest to the first end 520a may be smaller than the height H_1' of the bell mouth stopper adjacent to it. Accordingly, there may be an increase in the height H_1' of each successive bell mouth stopper until the middle of the set of bell mouth stoppers making up the lower bell mouth stoppers 520 is reached. Subsequently, there is a decrease in the height H_1' of each successive bell mouth stopper until the second end 520b of the lower bell mouth stoppers 520 is reached. The bell mouth stoppers of the lower bell mouth stoppers 520 are aligned in a successive manner at a regular interval, which leads to the formation of a locking surface 521 for engaging with the lower surface 413 of the ring 411 and the formation of a lower surface 522 for resting on a bell mouth support bearing surface 303 of the bell mouth outer support base 003. In a preferred embodiment, the number of lower bell mouth stoppers 520 is 12. In general, a smaller number of lower bell mouth stoppers 520 is preferred and the number of lower bell mouth stoppers 520 used should be sufficient to withstand a particular load at a particular orientation. Further, the number of lower bell mouth stoppers 520 used may also be dependent on the load that the bell mouth has to withstand.

In various embodiments and as shown in Fig. 5, the bell mouth outer support base 003 comprises an inner wall 301 that is shaped to accommodate the bell mouth body 410. As mentioned above, the at least one set of bell mouth stoppers 005 are adapted to engage the ring 411 of the bell mouth body 410. Specifically, the at least one set of bell mouth stoppers 005 is configured to engage an upper surface 412 and a lower surface 413 of the ring 411. Accordingly, in another embodiment, at least one set of bell mouth stopper slots

302 adapted to receive the at least one set of bell mouth stoppers 005 are machined into the inner wall 301 for locking the orientation of the bell mouth body 410. In some embodiments, the bell mouth stoppers 005 are arranged such that a plurality of slots are disposed around a circumference of the inner wall 301. Each of the bell mouth stopper slots 302 are arranged around the inner wall 301 with a gap between each adjacent stopper slot 301. In addition, each of the bell mouth stopper slots 302 extend from an outer edge of the bell mouth outer support base 003 to a bell mouth support bearing surface 303. Preferably, the bell mouth outer support base 003 is spherical in shape. In some embodiments, the inner wall 301 of the bell mouth outer support base 003 is spherical in shape.

In another embodiment, the bell mouth stoppers 005 are received in the bell mouth stopper slots 302 to lock the bell mouth body 410 in a desired azimuth angle with the assistance of the locking surfaces 511, 521 of bell mouth stoppers 005, which engage with the upper surface 412 of the ring 411 and the lower surface 413 of the ring 411, respectively. Consequently, locking of orientation of the bell mouth body 410 allows the riser tension to achieve a desired value and the riser can be safely pulled in and locked.

In various embodiments, the orientation of the bell mouth body 410 can be adjusted and locked in without a riser connected, for maintenance purposes or for the replacement of risers. Where appropriate, visual indications such as markings can be made on the bell mouth assembly 004 to assist in confirming the desired angles of the bell mouth body 410 and/or visual devices such as a camera may be suitably used to remotely view and check on the angle of the bell mouth body 410. If required, the orientation of the bell mouth can be adjusted by changing the at least one bell mouth stopper 005, such as the upper bell mouth stopper 510 and the lower bell mouth stopper 520. In a preferred embodiment, the adjustment of the orientation of the bell mouth body 410 is carried out without a riser connected.

In various embodiments, one or more of the components of the present invention may be made of relatively light weight material so that the one or more

components can be easily transported and replaced. For instance, the at least one set of bell mouth stoppers 005 may be made of light weight material. The material may be a metal (e.g. titanium and zinc) or a metal alloy (e.g. stainless steel and titanium alloy). In various embodiments, the one or more components
5 of the present invention may be machined in a short period of time such as two days. For instance, the at least one set of bell mouth stoppers 005 are machined pieces.

In various embodiments and as illustrated in Fig. 9, an installation frame may be provided to facilitate adjustment of the azimuth angle and/or top angle.
10 Advantageously, the installation frame provides a platform to hold the bell mouth assembly 004, particularly the bell mouth body 410, when setting the azimuth angle and/or top angle.

The embodiments described allow a flexible riser or a steel catenary riser to pass through and be hung from the bell mouth before fluidly coupling the riser
15 to a flowline connected to a side or a turret of an FPSO or production vessel. When a steel catenary riser is used, the present invention may further comprise additional top mechanism mountable on top of the bell mouth body 410, the top mechanism is capable of locking the ball joint of a steel catenary riser such as a steel lazy wave riser (SLWR). In various embodiments, the top mechanism
20 can be a flapper-type lock that utilizes two or more flappable structures to perform the locking functions so that the ball joint can be hung at the top mechanism.

The various embodiments can be used on-board FPSO, Floating Storage and Offloading vessel (FSO) or other production platforms, and can be used across
25 various industries that transport gas or liquid risers.

In various embodiments, the orientation of the bell mouth body 410 can be set and locked in a desired orientation before installation of a FPSO or changed after installation of the FPSO. This may be achieved by replacing the bell mouth stoppers 005. In some embodiments, the bell mouth stoppers 005 may be
30 press-locked inside the bell mouth housing structure (comprising the bell mouth

outer support base 003 and the ring 411) by the upper cover 320, which functions as a fastening means. The bell mouth stoppers 005 are press-locked due to engaging of the upper cover 320 with the at least one stoppers 005 via the gap between any two rods 324 to produce an interlock, thereby locking the orientation of the bell mouth and resulting in a bell mouth that has a better locking capacity compared to the bell mouth of Singapore patent no. 10201601701Y.

In various embodiments, the bell mouth stoppers are made of a lightweight and high-strength material. Examples of such lightweight and high-strength materials include, but not limited to, stainless steel, ASTM-A514, EN10029, S690 or other equivalent or even higher strength materials.

It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention. It is intended that all such modifications and adaptations come within the scope of the appended claims.

Further, it is to be appreciated that features from various embodiment(s), may be combined to form one or more additional embodiments.

Example

Non-limiting examples of the present disclosure will be further described, which should not be construed as in any way limiting the scope of the disclosure.

Example 1

A bell mouth in accordance with an embodiment of the present invention was designed. The static and dynamic capacity of the bell mouth have been analysed using ANSYS™, which is a software used to design products and semiconductors, as well as to create simulations that test a product's durability, temperature distribution, fluid movements, and electromagnetic properties.

Details of the ANSYS™ analysis are provided in Figures 10A to 10Z, 11A and 11B.

The following assumptions were made:

1. Bolts are arranged to only withstand the tension force, and bolts having
5 a dimension of 2-1/2" are strong enough to support a riser
2. Moment caused by shear force was included in the maximum moment
3. Three conditions were considered:
 - (a) DN48, flexible riser, top angle 8° and azimuth angle 25°;
 - (b) DN48, rigid riser, top angle 15° and azimuth angle 25°;
 - 10 (c) DN40, flexible riser, top angle 8° and azimuth angle 25°.

Each bell mouth will be subjected to a moment (Mt), shear force (Fs) and traction force (Ft) due to the riser that it is connected to.

There are 24 locking components inside the external housing of the bell mouth. The angle locking of the bell mouth is designed to be able to achieve safe
15 locking angle even if 10% of the locking components fail for an unexpected reason. Table 1 shows the designed load and angle capacity of the bell mouth, while Table 2 shows the possible azimuth angles at different top angles.

Table 1. Load Capacity at Different Top Angles

Adjustable TOP Angle	Max. Traction Ft (KN)	Max. Total Moment Mt (kN.m)	Max. Shear Fs (kN)
3~8° (flexible riser, 2.5 ~ 10")	0	6900	1617
13~15° (rigid riser)	6931	1673	1140

20 Table 2. Possible Azimuth Angles at Different Top Angles

AZIMUTH +/- (degrees)	Range of TOP ANGLE (degrees)
0 ~ 25	3 ~ 8°
0 ~ 25	13 ~ 15°

Accordingly, Example 1 shows that the bell mouth of the present invention, which has an adjustable top angle and/or azimuth angle, has a good locking capacity which is comparable to other prior art bell mouths.

CLAIMS

1. An apparatus for connecting to a riser, the apparatus comprising a bell
5 mouth body for allowing the riser to pass therethrough, at least one set
of bell mouth stoppers for setting an orientation of the bell mouth body
and an upper cover for locking the bell mouth body at the orientation;
wherein the bell mouth body comprises a ring configured around an
outer surface of the bell mouth body and wherein the at least one set of
10 bell mouth stoppers is configured to engage the upper cover with the
ring.
2. The apparatus of claim 1, further comprising a lower cover for covering
the ring.
- 15 3. The apparatus of claim 1 or 2, wherein the ring comprises an upper
surface and a lower surface, and wherein the at least one set of bell
mouth stoppers engages with the upper surface and the lower surface
of the ring.
- 20 4. The apparatus of any one of the preceding claims, wherein the upper
cover comprises a first half and a second half, wherein each half
comprises a set of rods spaced apart from each other via a gap, and
wherein the at least one set of bell mouth stoppers engages the gap to
produce an interlock.
- 25 5. The apparatus of any one of the preceding claims, wherein the at least
one set of bell mouth stoppers comprises upper bell mouth stoppers and
lower bell mouth stoppers.
6. The apparatus of claim 5, wherein the upper bell mouth stoppers
comprises at least one bell mouth stopper, each bell mouth stopper
30 comprising a first portion and a second portion, wherein the height of the

first portion and the height of the second portion changes from a first end to a second end of the upper bell mouth stoppers.

7. The apparatus of claim 5, wherein the lower bell mouth stoppers comprises at least one bell mouth stopper, each bell mouth stopper comprising a first portion and a second portion, wherein the height of the first portion and the height of the second portion changes from a first end to a second end of the lower bell mouth stoppers.
8. The apparatus of any one of the preceding claims, further comprising a bell mouth outer support base.
9. The apparatus of claim 8, wherein the bell mouth outer support base comprises an inner wall and a set of bell mouth stopper slots for receiving at least one bell mouth stopper, wherein the set of bell mouth stopper slots are positioned on the inner wall of the bell mouth outer support base.
10. The apparatus of claim 9, wherein the inner wall of the bell mouth outer support base is spherical in shape and wherein the ring comprises a spherical outer surface engageable with the inner wall of the bell mouth outer support base.
11. The apparatus of any one of the preceding claims, wherein the at least one set of bell mouth stoppers is made of a lightweight and high-strength material.
12. The apparatus of claim 11, wherein the light weight and high strength material is stainless steel, ASTM-A514, EN10029 or S690.