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(54) **Title**: BEND STIFFENER

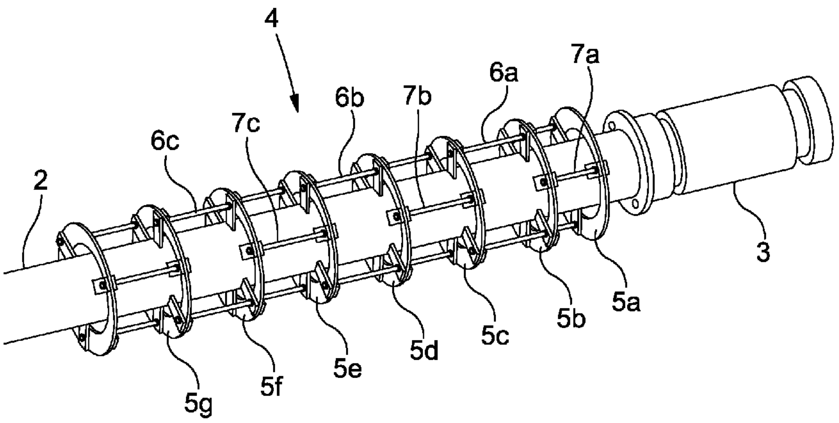

Figure 2

(57) **Abstract**: A bend stiffener 4 comprising a plurality of beams 5a-g arranged to be disposed around a tubular member 2. A support is provided for connecting the bend stiffener 4 to the tubular member 2. A first rigid rod 6a connects a first beam 5b of the plurality of beams to a second beam 5c of the plurality of beams. The first rigid rod 6a is connected at a surface of the first beam 5b such that it does not lie on the same axis as a second rigid rod 7a connected at an opposite surface of the first beam 5a. A stiffness of any of the plurality of beams and connectors between beams and rods provides bend stiffening to the tubular member 2.

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Bend Stiffener

TECHNICAL FIELD

The present invention relates to the field of bend stiffeners.

BACKGROUND

Risers and umbilicals are typically used in offshore hydrocarbon production to transport fluids (such as produced hydrocarbons or hydraulic fluids) between a well head at the sea bed and a surface vessel, for example a rig or a drill ship. Motion of the surface vessel caused by wind, waves, ocean currents and so on, leads to bending of the risers and umbilicals. This places periodic mechanical stresses on the risers and/or umbilicals, which can lead to mechanical failure.

The weakest point of each riser or umbilical is the point immediately adjacent to the connection to the surface vessel. This is the region subject to the highest mechanical stress, and therefore the region most likely to fail.

In order to strengthen the riser at this point, it is known to attach a bend stiffener 1 to the riser (the word riser is used herein to describe any pipe or umbilical extending from the surface vessel towards the well head or other subsea installation), as illustrated in Figure 1. The bend stiffener 1 is disposed around a riser 2 that is connected at a riser connection point 3 to a surface vessel. This point is known as the “hang-off”.

Existing bend stiffeners in use tend to be polyurethane stiffeners moulded into a truncated conical shape. Other types of material that have similar elastic properties to polyurethane may be used.

Conical bend stiffeners have an insulating effect around the riser, as they do not allow free movement of water. If the riser is carrying hot fluids, such as high temperature hydrocarbons, this insulating effect can give rise to high temperatures between the bend stiffener and the riser. Similarly, if an umbilical contains a high voltage power cable, this can give rise to heat. If the heat cannot dissipate away from the riser in the hang-off region, if may damage the riser or the bend stiffener. Heat is known to degrade polyurethane, so over time the bend stiffener and any polymeric outer sheath on the riser will become more prone to mechanical failure. This leads to a reduction in the lifetime of the outer sheath and the bend stiffener.

Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present disclosure as it existed before the priority date of each of the appended claims.

SUMMARY

Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

According to a first aspect, there is provided a bend stiffener comprising a bend stiffener comprising:

a support for connecting the bend stiffener to a tubular member;

a plurality of beams arranged to be disposed around the tubular member, wherein each beam is connected, using connectors, to a first set of rigid rods,

the first set of rigid rods being aligned along a first axis arranged to be offset from but substantially parallel to a main axis of the tubular member, such that the rigid rods do not form a contiguous path along the first axis.

In a preferred advantage a bend stiffener may be provided that is less prone to thermally insulating the riser around the hang-off point.

As an option, each beam is substantially flexible. This allows the stiffener to flex while still providing bend stiffening.

Each beam optionally comprises a flexible annular disc disposed such that the tubular member passes through an opening of the annular disc.

The annular disc optionally comprises a split thereby allowing it to be fitted to the tubular member. An advantage of this is that where the tubular member is a riser, the bend stiffener can be retro-fitted to an existing riser.

Each beam is optionally disposed in a plane substantially perpendicular to a main axis of the tubular member.

An elastic pad is optionally disposed at connectors between the beams and rods, the elastic pad providing bend stiffening to the tubular member.

A support is optionally connected to the first beam, the support having an attachment point for attaching to the tubular member. Alternatively, a support may be connected to the first rod, the support having an attachment point for attaching to the tubular member. As a further alternative, a support is connected to a connector connecting the first rod to the first beam, the support having an attachment point for attaching to the tubular member.

Each beam optionally has a selected stiffness according to its location along a main axis of the tubular member. In this way, the stiffness can be varied along the length of the bend stiffener. This allows, for example, a beam to have a higher stiffness in proximity with the hang-off point, compared to a beam remote from the hang-off point. The stiffness may be selected by varying any of a thickness of each beam and an elastic modulus of each beam.

According to a second aspect, there is provided a tubular member assembly comprising a tubular member and a bend stiffener as described above in the first aspect. Examples of tubular members include risers and umbilicals.

According to a third aspect, there is provided a method of fitting a bend stiffener to a tubular member. A plurality of beams is disposed around the tubular member. Each beam is connected using connectors to a first set of rigid rods, the first set of rigid rods being aligned along a first axis offset from but substantially parallel to a main axis of the tubular member. The rigid rods therefore do not form a contiguous path along the first axis. The bend stiffener is attached to the tubular member at the beams, the rigid rods and/or the connectors using supports.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates schematically a cross-section view of a known bend stiffener and riser;

Figure 2 is a perspective view of an exemplary bend stiffener;

Figure 3 is a perspective view of an exemplary bend stiffener showing bending;

Figure 4 illustrates schematically a cross-section view of an exemplary connector between a road and an annular disc;

Figure 5 illustrates schematically a cross-section view of an exemplary connector between a road and an annular disc under tension;

Figure 6 illustrates schematically a side elevation view of a portion of a bend stiffener attached to a riser at a connection point;

Figure 7 illustrates schematically a side elevation view of a portion of a bend stiffener attached to a riser at an annular disc;

Figure 8 illustrates schematically a side elevation view of a portion of a bend stiffener attached to a riser at a rigid rod; and

Figure 9 is a flow diagram showing exemplary steps for fitting a bend stiffener to a tubular member.

DETAILED DESCRIPTION

Figures 2 and 3 show perspective views of an exemplary bend stiffener 4. The bend stiffener 4 surrounds a tubular member such as a riser 2 or other type of pipe or umbilical, and is disposed towards the hang-off point below the riser connection point 3.

The bend stiffener comprises a plurality of flexible annular discs 5a-g. Each annular disc is disposed around the riser 2 such that the riser 2 passes through the centre of each annular disc 5a-5g.

Several sets of rigid rods are provided to connect the flexible annular discs 5a-5g. In this example, two sets of rigid rods 6a-c and 7a-c are marked in Figure 3. A first set of rigid rods 6a-c is disposed substantially along the same first axis, the first axis being substantially parallel to a main axis of the riser 2. However, the rigid rods on this axis are disposed such that they connect alternate annular discs. For example, the first rigid rod 6a of the first set of rigid rods connects annular disc 5b to annular disc 5c. The second rigid rod 6b of the first set of rigid rods connects annular disc 5d to annular disc 5e. The third rigid rod 6c of the first set of rigid rods connects annular disc 5f to annular disc 5g. Along the first axis, there are no rigid rods between annular disc 5c and annular disc 5d, or between annular disc 5e and annular disc 5f. This ensures that the first set of rigid rods 6a-c does not form a contiguous path along the first axis, and so the flexibility of the annular discs allows a degree of flexure in the bend stiffener.

Similarly, a second set of rigid rods 7a-c is disposed substantially along the same second axis, the second axis being offset from the first axis but also substantially parallel to the main axis of the riser 2. Again, the rigid rods of the second rigid rods are disposed such that they connect alternate annular discs. For example, the first rigid rod 7a of the second set of rigid rods connects annular disc 5a to annular disc 5b. The second rigid rod 7b of the second set of rigid rods connects annular disc 5c to annular disc 5d. The third rigid rod 7c of the second set of rigid rods connects annular disc 5e to annular disc 5f. Along the second axis, there are no rigid rods between annular disc 5b and annular disc 5c, or between annular disc 5d and annular disc 5e. This ensures that the second set of rigid rods 7a-c does not form a contiguous path along the second axis, and so the flexibility of the annular discs allows a degree of flexure in the bend stiffener.

The above description refers only to two axes, but it will be appreciated that any suitable number of axes may be used provided no axis comprises a contiguous path of rods. In the examples of Figures 2 and 3, there are six axes disposed around the riser 2 having non-contiguous rods connecting annular discs.

Note that each annular disc 5a-g may be provided with a split in it or as tow halves. The combination of the split and the flexibility of the annular discs 5a-g allows the bend stiffener to be retrofitted to an existing riser 2 without having to disconnect the riser at the hang-off point.

As shown by the dotted lines in Figure 3, when a bending moment is placed on the bend stiffener 4, the elasticity of the flexible annular discs 5a-5g allows the bend stiffener to flex owing to flexure of the annular discs 5a-g. The required stiffness can be determined by using annular discs 5a-g with different stiffness. This may be achieved by selecting a material with the desired elastic modulus, and/or using an annular disc having a thickness that gives the required stiffness. Note that this can also be used to vary the amount of flexure allowed along the length of the bend stiffener. For example, the annular discs 5a and 5b located towards the hang-off point at the riser connection point 3 may have a higher stiffness than the annular discs 5f, 5g at the opposite end of the bend stiffener. This provides more stiffness at the hang-off point, and therefore provides a greater degree of protection to the riser 2 at the hang-of point where stress tends to be highest.

As the rods are rigid, they act only as spacers between the annular discs 5a-g, and do not significantly contribute to flexure of the bend stiffener 4. However, the rods provide an open structure and so water can pass directly over the riser 2. This ensures that any heat generated by hot fluids or electric cables can be dissipated, and the bend stiffener 4 does not act as a thermal barrier insulating the riser 2 towards the hang-off point.

Note that a degree of flexibility can also be introduced by providing some flexibility at a connector between each rod and annular disc. Figures 4 and 5 illustrate an exemplary connector between a rod 6a and an annular disc. The rod 6a goes through the annular disc 5c and is secured by a threaded nut 8, although it will be appreciated that any type of connector may be used. A first washer 9 is disposed between the nut 8a and the annular disc 5c which holds a first elastic pad 10 between the first washer 9 and the annular disc 5c. A second washer 11 is disposed on the opposite side of the annular disc 5c to the first washer 10, and a second elastic pad 12 is disposed between the second washer 11 and the annular disc 5c.

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Figure 4 shows the connector when there is no bending of the bend stiffener 4. However, when the bend stiffener 4 flexes, the connector is also placed under stress. In the example of Figure 5, the arrow 13 shows the direction of tension. In this case, the first elastic pad 10 is compressed and the second elastic pad 12 expands elastically. In this way, the elastic pads 10, 12 of the connector provide a degree of flexure in addition to the degree of flexure provided by the flexible annular discs 5a-g.

The thickness and/or elastic modulus of the elastic pads 10, 12 can be selected to provide different degrees of stiffness at different points of the bend stiffener 4.

There are various different ways in which the bend stiffener can be attached to the riser 2. Figure 6 shows a first connector 14 attaching annular disc 5c to rod 7b. A first support 15 is used to attach the first connector 14 to the riser 2 b any suitable means. A second connector 16 attaches rod 7b to annular disc 5d, and a second support 17 attaches second connector 16 to the riser 2. In this way, the bend stiffener is attached to the riser using supports at the annular discs.

Figure 7 shows first support 15 attaching annular disc 5c directly to the riser, and second support 17 attaching annular disc 5d directly to the riser.

Figure 8 shows a support 18 attaching rigid rod 7b directly to the riser, such that the annular discs 5c, 5d do not directly contact the riser 2.

Figure 9 is a flow diagram showing exemplary steps for fitting a bend stiffener 4 to a riser 2. The following numbering corresponds to that of Figure 9:

S1. Flexible annular discs 5a-g are disposed around the riser 2 towards the hang-off point. This may be before the riser 2 is fitted at the riser connection point 3, or by using split flexible annular discs that can be retrofitted to a riser that is already connected at the riser connection point 3.

S2. The annular discs 5a-g are connected together using sets of rigid rods 6a-c, 7a-c such that each set of rigid rods does not form a contiguous path along an axis substantially parallel to a main axis of the riser 2.

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S3. The bend stiffener 4 is attached to the riser 2 using any suitable supports, either at the connectors as shown in Figure 6, the annular discs as shown in Figure 7, or the rods as shown in Figure 8.

Note that the above steps may be carried out in any suitable order. For example, step S2 may be carried out first to assemble the entire bend stiffener 4 before it is fixed to the riser 2.

Note that the above description refers to annular discs providing stiffness but allowing some flexibility of the riser. This is a preferred embodiment, but it will be appreciated that any suitable beam may be used. For example, in the example of Figure 3, annular disc 5c could be replaced by three beams, each beam connecting a pair of adjacent rods. Alternatively, each annular disc may be replaced by a pair of semicircular beams. Similarly, each annular disc may instead have a substantially hexagonal shape (in the example where six axes of rods running parallel to a main axis of the riser 2 are used). The skilled person will be able to develop other configurations.

Similarly, the annular discs 5a-g are shown as lying in a plane substantially perpendicular to the main axis of the riser 2. It will be appreciated that the discs may be inclined with respect to that plane. This can further stiffen the bend stiffener in particular directions.

The bend stiffener 4 describes above need not contain any mercury, unlike existing polyurethane bend stiffeners, and so is less harmful to the environment. Furthermore, the bend stiffener 4 does not provide thermal insulation to the riser 2, and so is less likely to cause thermal degradation of the bend stiffener 2 or any polymeric sheaths on the riser 1. As described above, it is possible to produce the annular discs 5a-g in semicircular halves or with splits to enable mounting or remounting the bend 4 stiffener with the riser connection point 3 of the riser 2 already connected.

It is described above that the degree of stiffening provided by the bend stiffener 4 can be varied along its length by using annular discs of different thickness/elasticity. The non-linear stiffening of the bend stiffener 4 allows designers to optimize the stiffness of the bend stiffener 4 for both extreme loads and fatigue loads on the riser 2.

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It will be appreciated by the person of skill in the art that various modifications may be made to the above-described embodiments without departing from the scope of the present invention as described in the appended claims. For example, the embodiments above use the example of a riser 2, but the bend stiffener 4 can be used with any type of tubular member such as a riser or an umbilical.

CLAIMS:

1. A bend stiffener comprising:

a support for connecting the bend stiffener to a tubular member;

a plurality of beams arranged to be disposed around the tubular member, wherein each beam is connected, using connectors, to a first set of rigid rods,

the first set of rigid rods being aligned along a first axis arranged to be offset from but substantially parallel to a main axis of the tubular member, such that the rigid rods do not form a contiguous path along the first axis.

2. The bend stiffener according to claim 1, wherein each beam is substantially flexible.

3. The bend stiffener according to claim 1 or 2, wherein each beam comprises a flexible annular disc disposed such that the tubular member passes through an opening of the annular disc.

4. The bend stiffener according to claim 3, wherein the annular disc comprises a split thereby allowing it to be fitted to the tubular member.

5. The bend stiffener according to any one of claims 1 to 4, wherein each beam is disposed in a plane substantially perpendicular to a main axis of the tubular member.

6. The bend stiffener according to any one of claims 1 to 5, further comprising an elastic pad disposed at connectors between the beams and rods, the elastic pad providing bend stiffening to the tubular member.

7. The bend stiffener according to any of claims 1 to 6, further comprising a support connected to the first beam, the support having an attachment point for attaching to the tubular member.

8. The bend stiffener according to any of claims 1 to 6, further comprising a support connected to the first rod, the support having an attachment point for attaching to the tubular member.

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9. The bend stiffener according to any of claims 1 to 6, further comprising a support connected to the a connector connecting the first rod to the first beam, the support having an attachment point for attaching to the tubular member.

10. The bend stiffener according to any one of claims 1 to 9, where each beam has a selected stiffness according to its location along a main axis of the tubular member.

11. The bend stiffener according to claim 10, wherein a beam in proximity to a hang-off point of the tubular member has a higher stiffness than a beam remote from the hang-off point.

12. The bend stiffener according to any one of claims 10 or 11, wherein the stiffness is selected by varying any of a thickness of each beam and an elastic modulus of each beam.

13. A tubular member assembly comprising a tubular member and a bend stiffener according to any one of claims 1 to 12.

14. The tubular member assembly according to claim 13, wherein the tubular member is any of a riser and an umbilical.

15. A method of fitting a bend stiffener to a tubular member, the method comprising:

disposing a plurality of beams around the tubular member;

connecting each beam using connectors to a first set of rigid rods, the first set of rigid rods being aligned along a first axis offset from but substantially parallel to a main axis of the tubular member, such that the rigid rods do not form a contiguous path along the first axis; and

attaching any of the beams, the rigid rods and the connectors to the tubular member using supports.

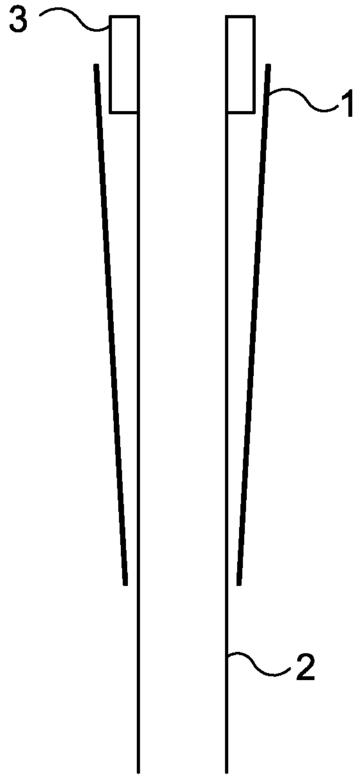

Figure 1 (prior art)

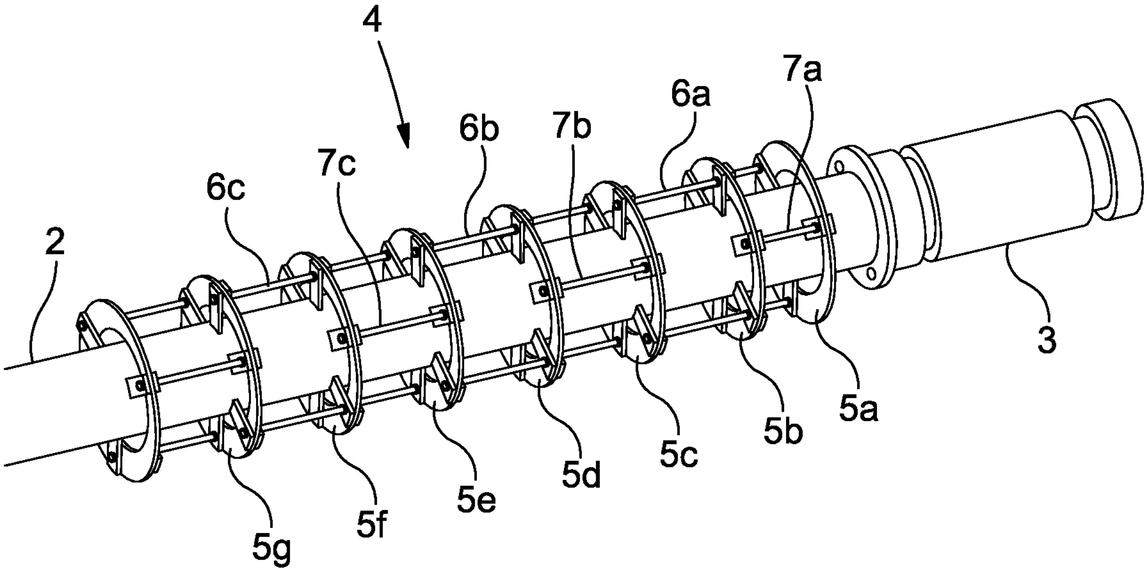

Figure 2

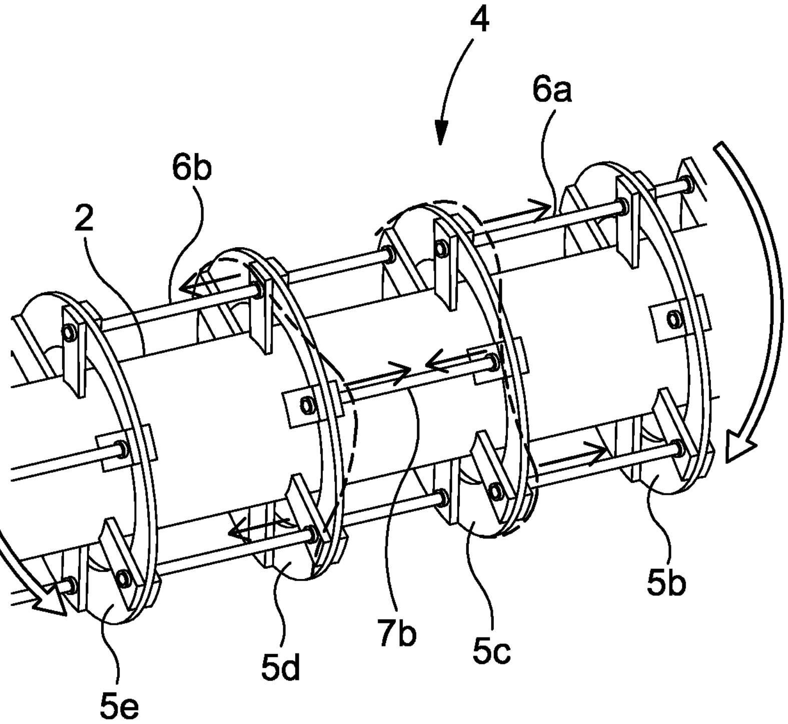

Figure 3

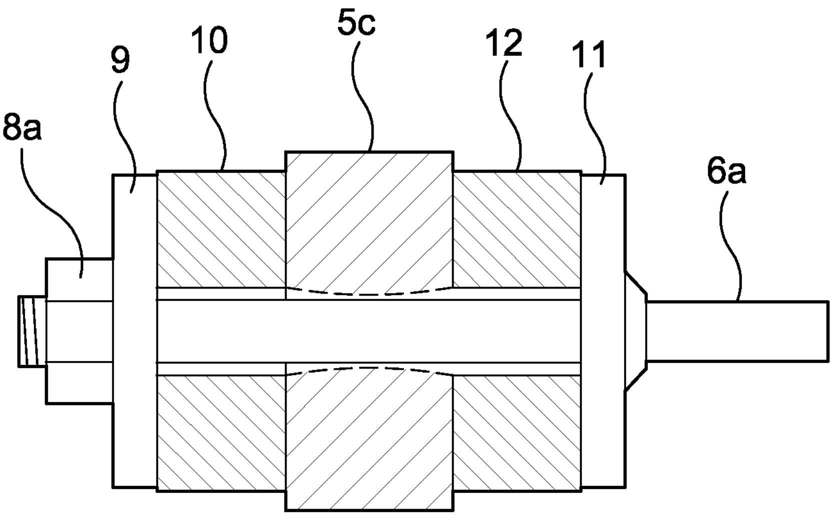

Figure 4

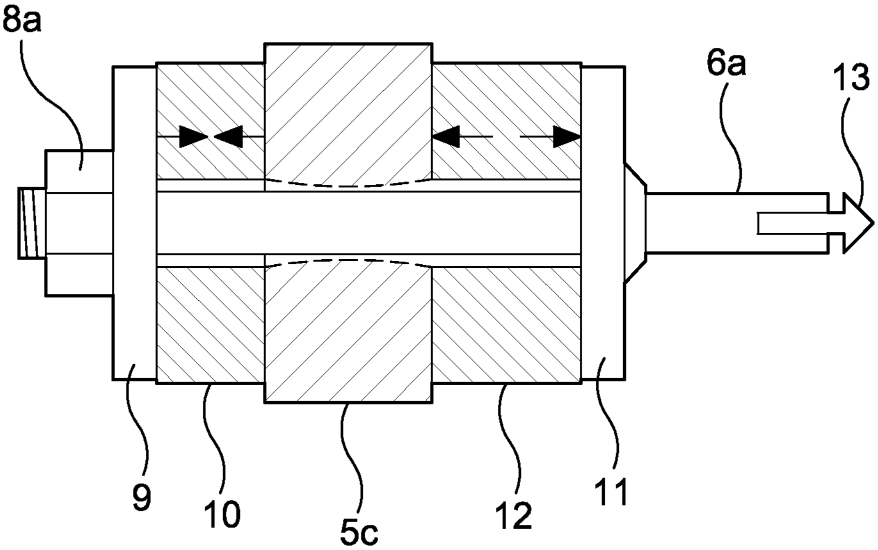

Figure 5

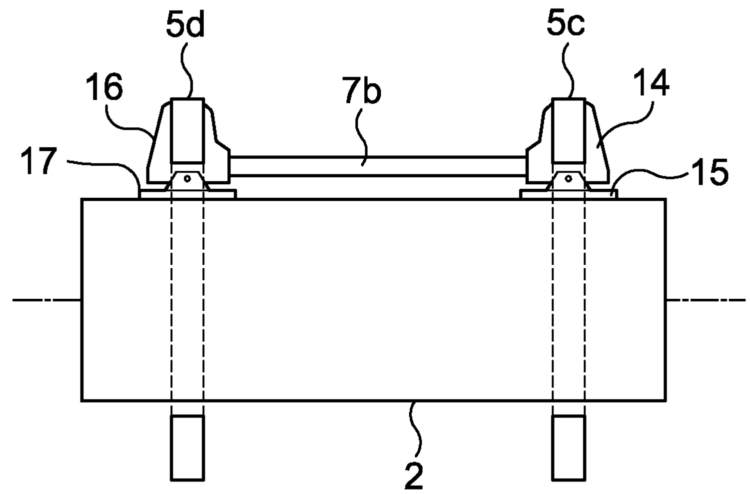

Figure 6

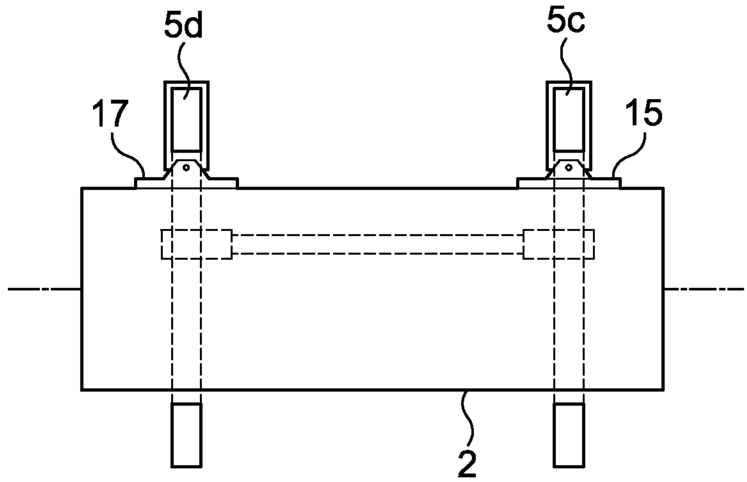

Figure 7

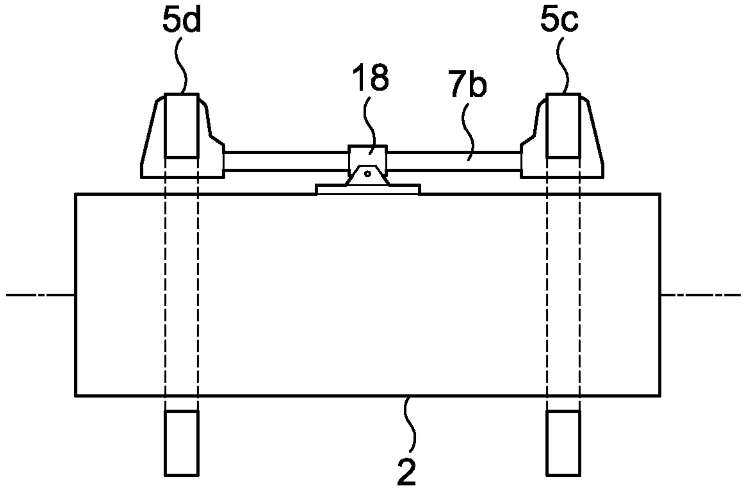

Figure 8

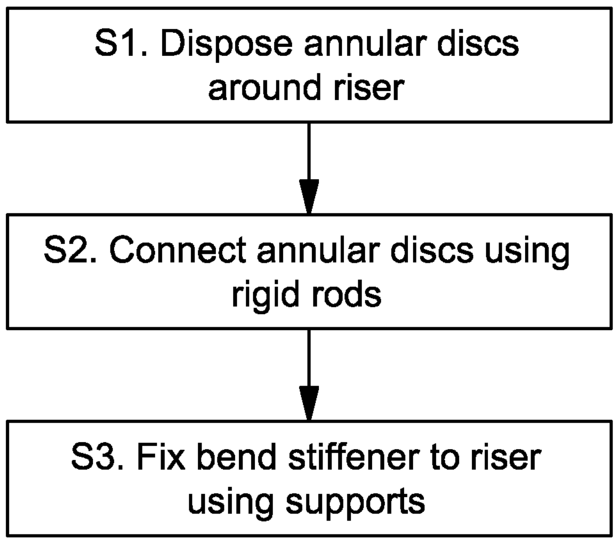
S1. Dispose annular discs around riser
S2. Connect annular discs using rigid rods
S3. Fix bend stiffener to riser using supports

Figure 9