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F2U U547 U558

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US 4768992 A

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(54) Abstract Title

Flexible annular coupling with predetermined buckling direction

(57) A flexible annular coupling has circumferentially spaced fixing portions (10) connected by flexible leaves (11). The leaves are arranged so that if they are caused to buckle by compressive stresses applied between their ends they will always buckle in the same direction. The leaves may be curved in their central parts (11a) so that they are offset to one side of a plane (14a) perpendicular to the rotary axis (14) of the coupling. Alternatively the leaves may be made of layers (26, 27) of different stiffnesses or transition portions (17) between the leaves and the fixing portions (10) may be shaped to produce the unidirectional buckling.

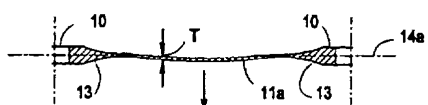


FIG 3

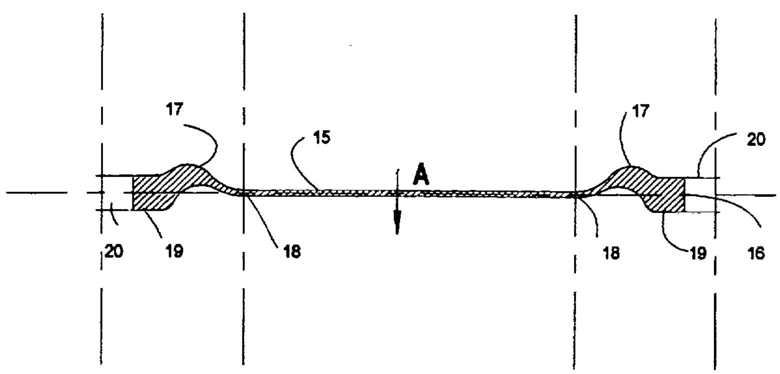


FIG 4

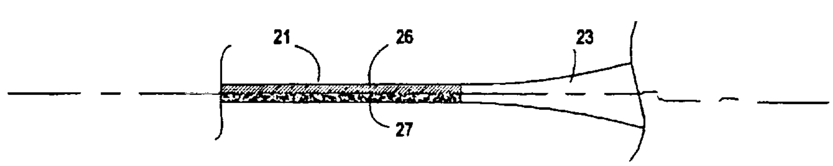


FIG 6

GB 2 342 424 A

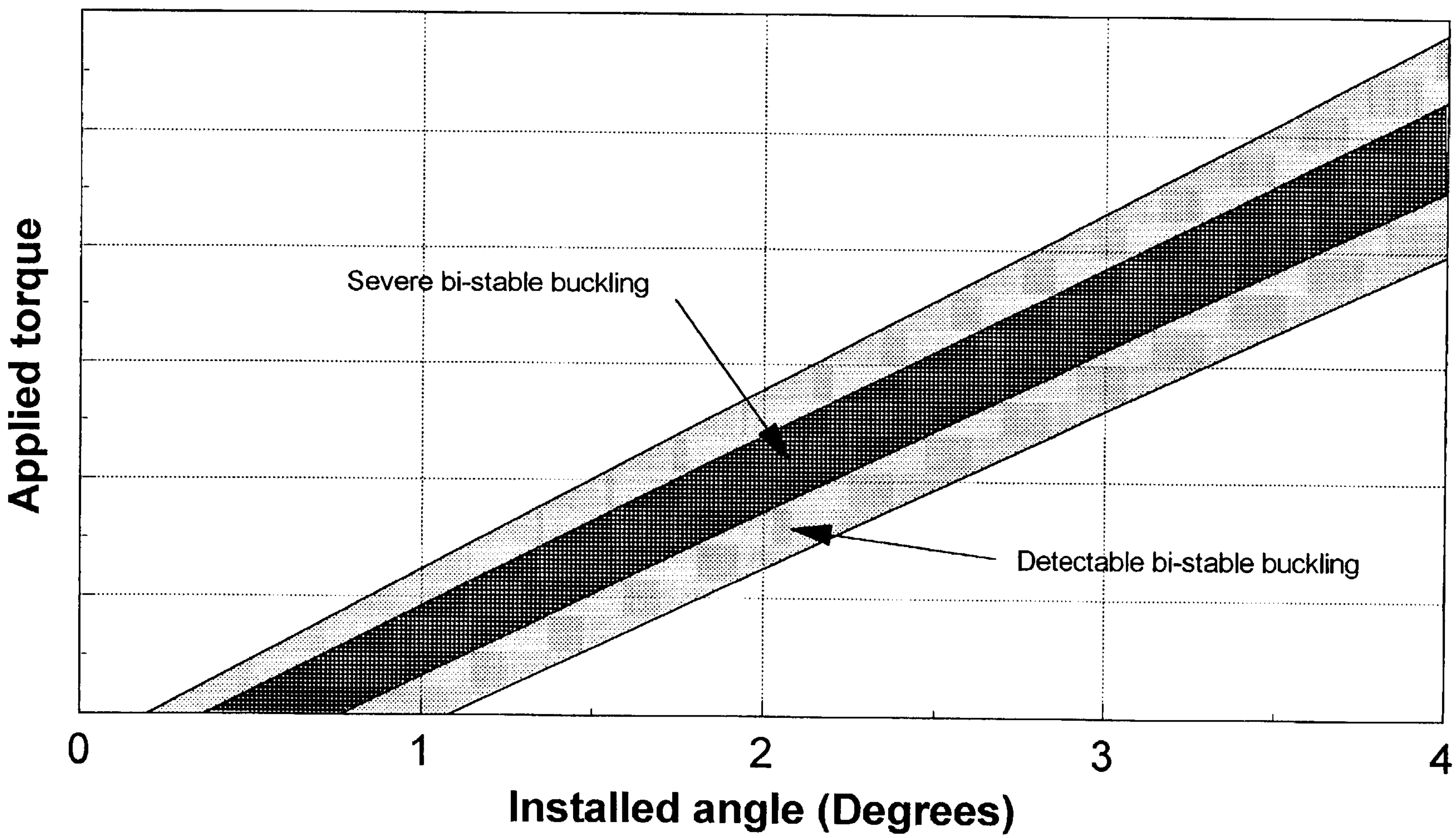
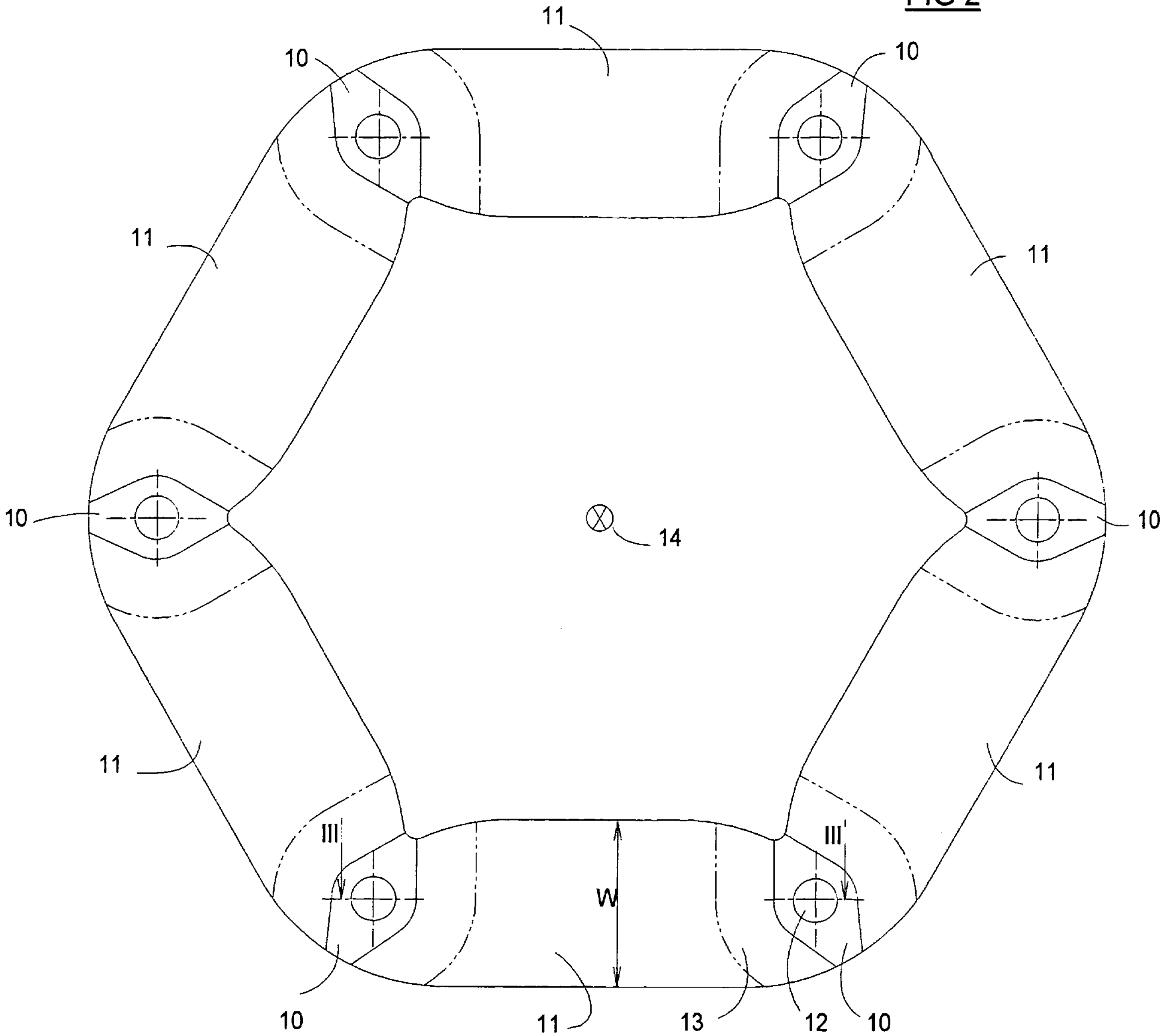

Applied torque
Severe bi-stable buckling
Detectable bi-stable buckling
0
1
2
3
4
Installed angle (Degrees)

FIG 1

FIG 2


11
10
10
11
11
10
14
10
11
11
III
III
W
10
11
13
12
10

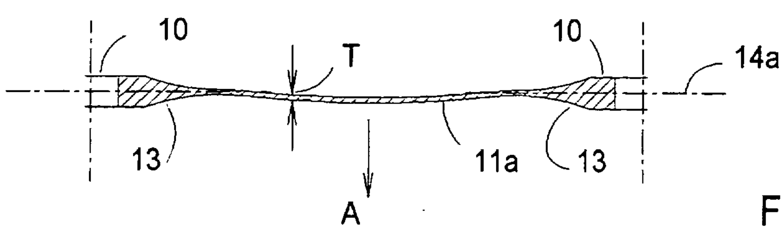

10
T
10
14a
13
11a
13
A

FIG 3

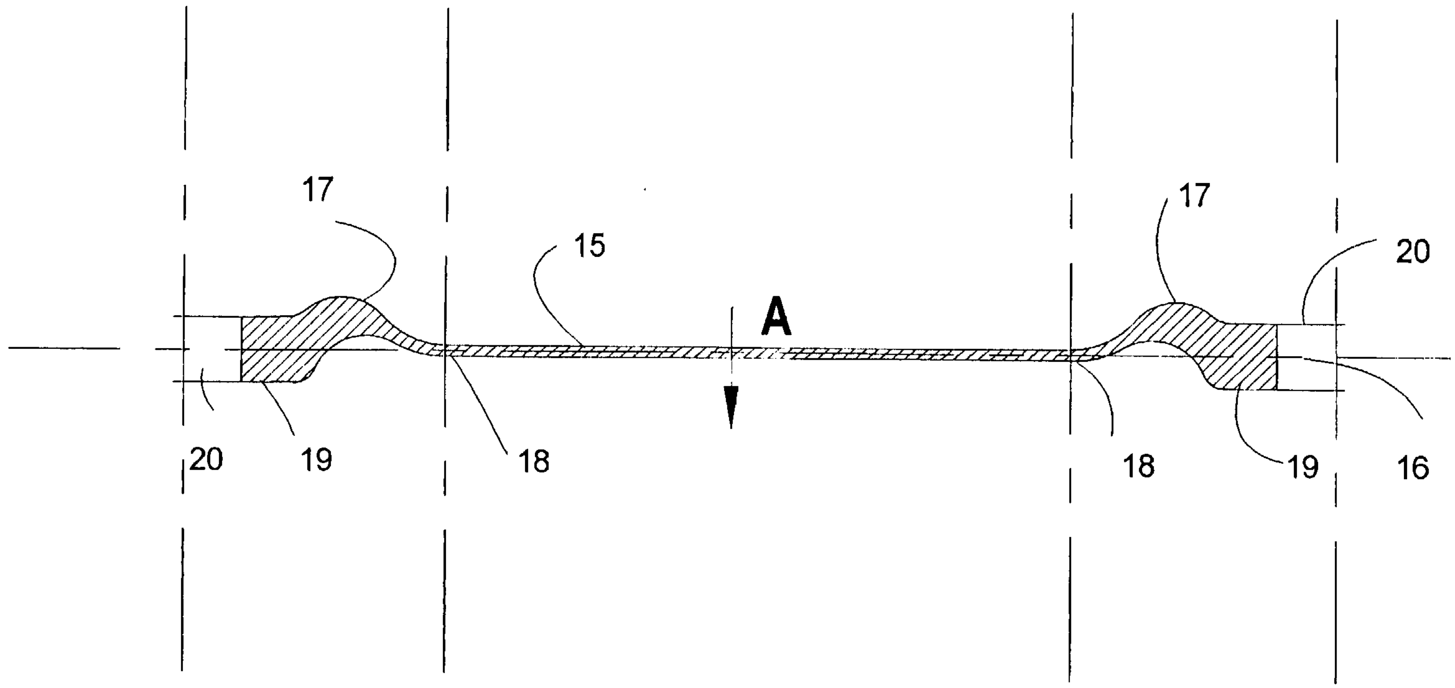


FIG 4

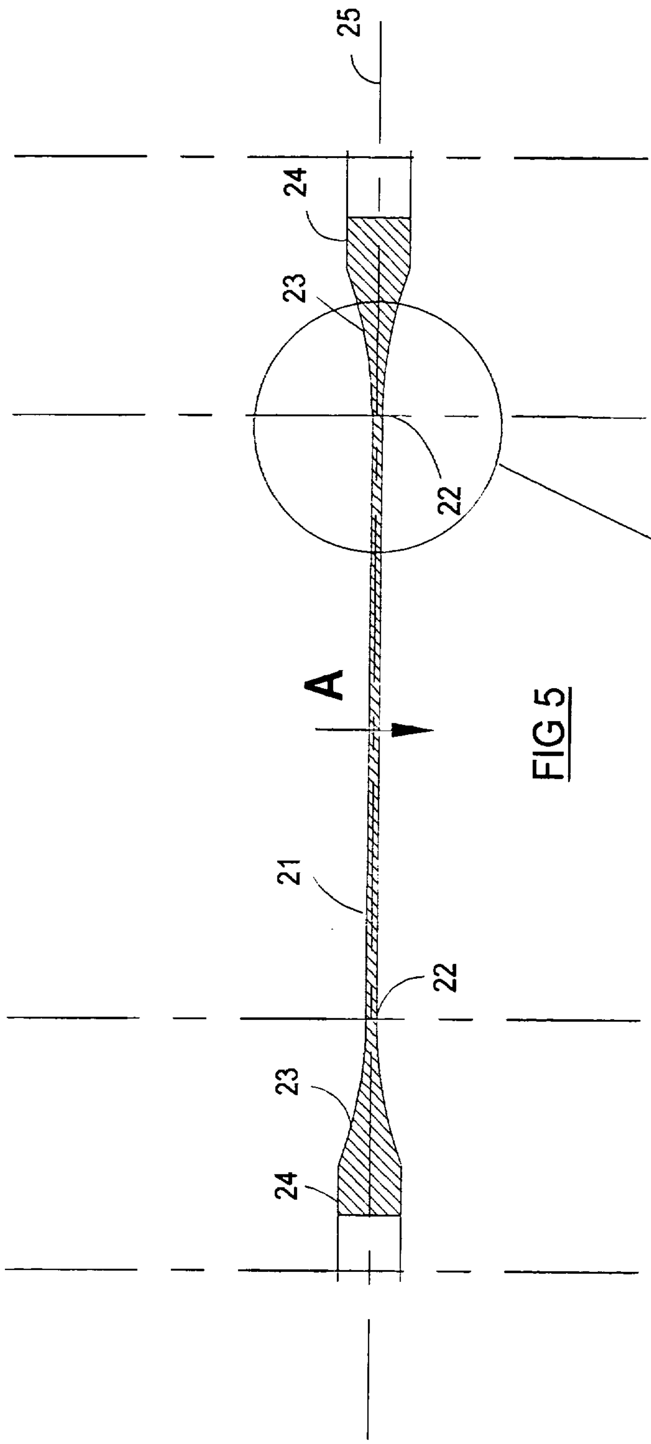


FIG 5

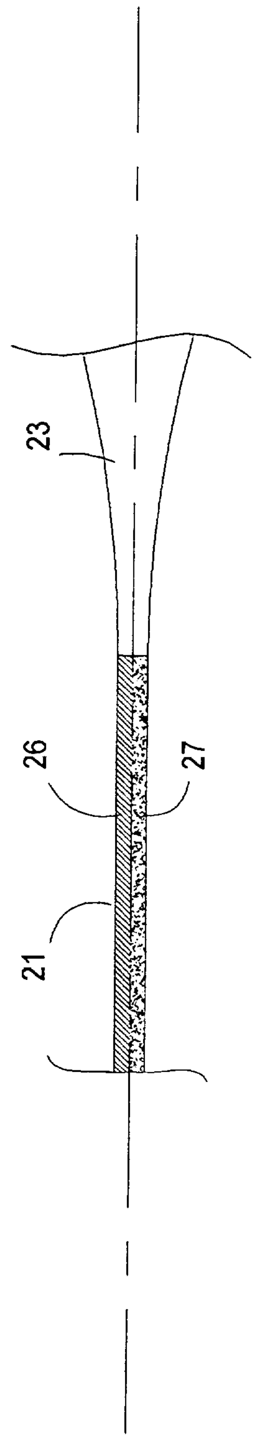


FIG 6

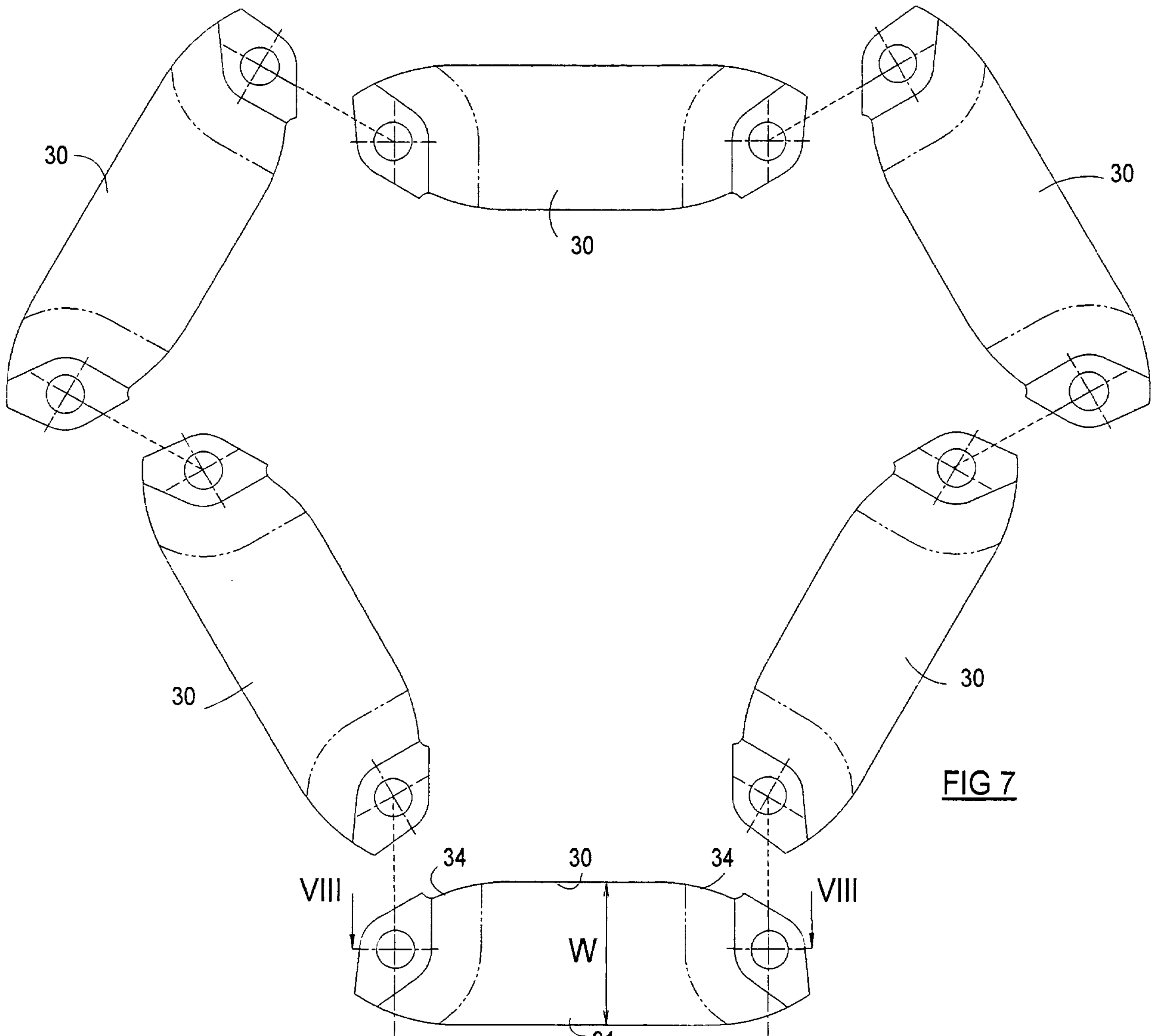


FIG 7

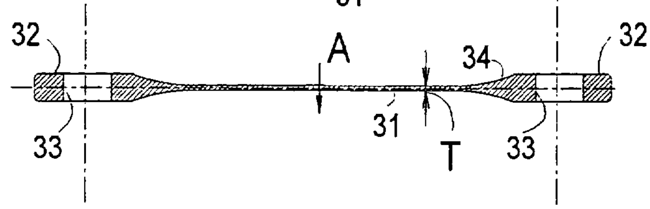


FIG 8

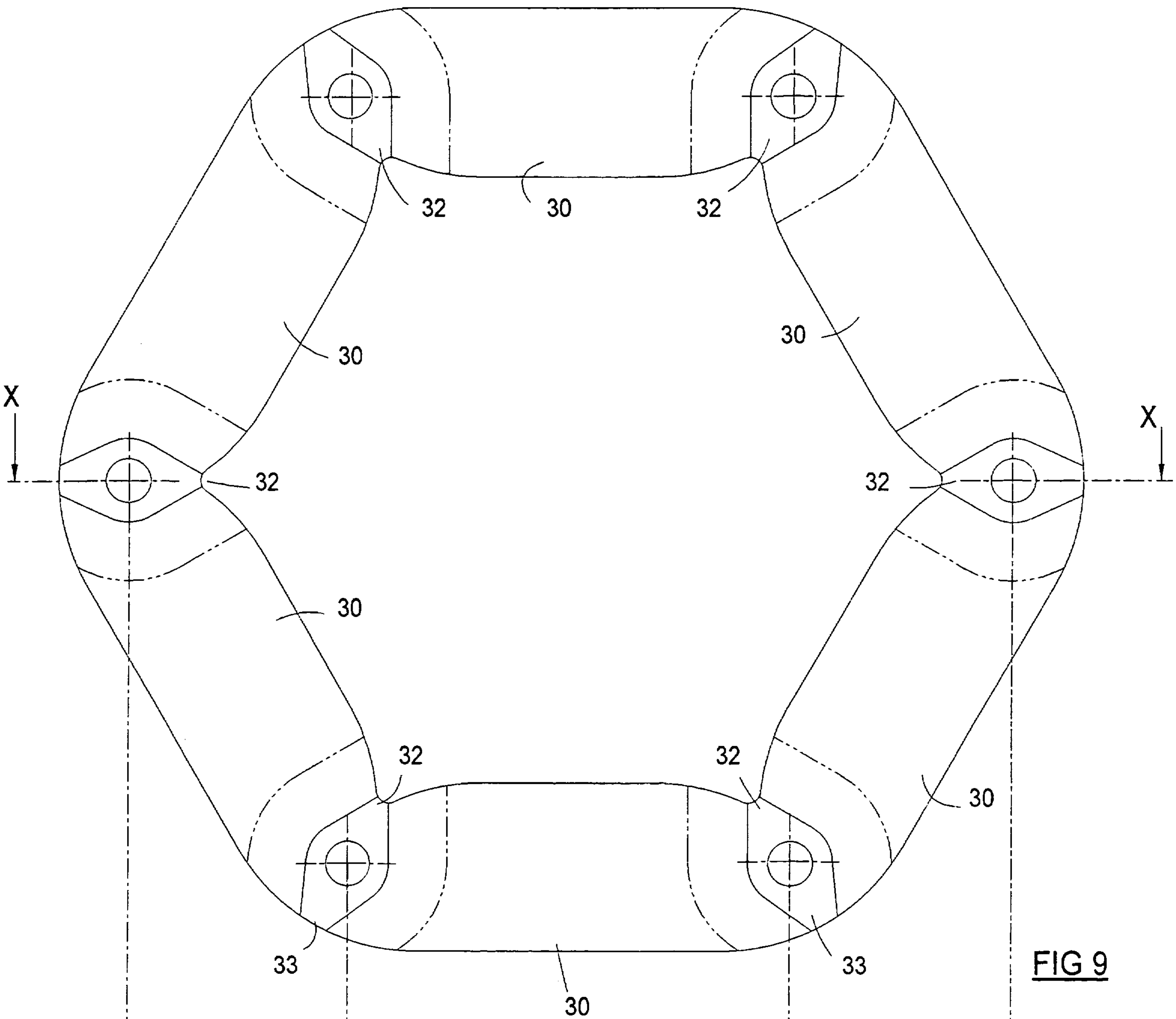

X
X
30
32
32
30
30
30
30
32
32
32
32
30
33
33
30

FIG 9

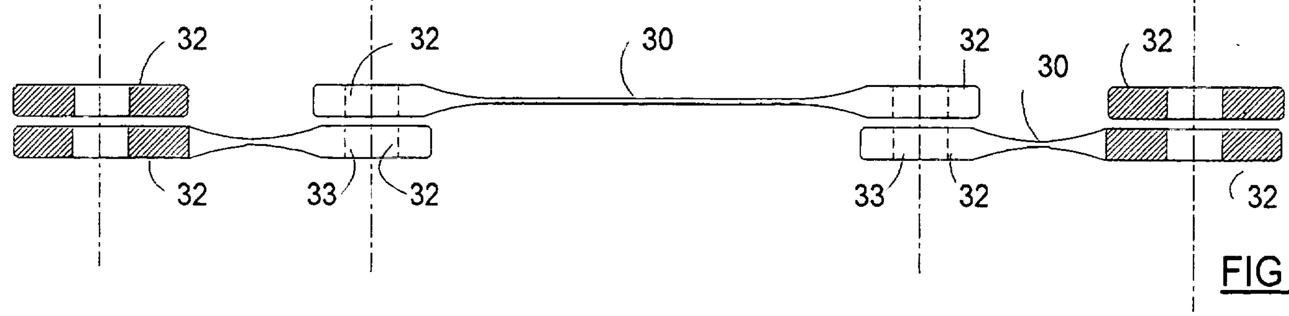

32
32
30
32
30
32
32
33
32
33
32
32

FIG 10

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PATENTS ACT 1977

Title: FLEXIBLE COUPLING

Description of Invention

This invention relates to a flexible coupling which is of annular shape and comprises a plurality of fixing portions spaced circumferentially about the coupling and leaves extending between each adjacent pair of fixing portions. The latter are arranged for connection to two rotary members which are to be coupled. In use one rotary member is connected to alternate ones of the fixing portions and the other rotary member is connected to the other fixing portions.

The term "annular shape" is used herein to include not only a circular ring but also a polygon or other shape having an aperture surrounded by the leaves.

Couplings of the type described above are known made of discrete laminations of steel and as a unitary composite (fibre-reinforced plastic) laminated structure. Each leaf has a comparatively small thickness in the direction axially of the coupling, i.e. parallel to its axis of rotation in use, and has a relatively large width in the direction radially of the coupling (i.e. radially of such axis).

When torque is applied to a flexible coupling of the type described in the preceding paragraph, tensile strain develops in those leaves subjected to tensile forces and a compressive displacement is imposed on those leaves subjected to compressive forces. Small compressive displacements may be accommodated without buckling by compressive strain in the leaf but, for couplings of the type described, typical compressive displacements cause buckling of the leaves. For a flexible coupling rotating at 0° installed angle, i.e. with the axes of the coupled rotary members aligned, whilst transmitting torque the leaves retain their buckled shape throughout continuous operation. When a flexible coupling is used at an installed angle, i.e. where there is angular misalignment between the axes of rotation of the coupled rotary members, tensile strain is imposed on all the leaves. If the strain due to the installed angle is smaller than the strain due to applied torque, stable buckling of the leaves loaded in compression is retained throughout rotation. This corresponds to the area of the operating diagram shown in Figure 1 above the shaded zone. If the strain due to the installed angle is bigger than the strain due to applied torque, then there is no buckling of the leaves loaded in compression. This corresponds to the area of the operating diagram of a coupling of the type described in Figure 1 below the shaded zone. A bi-stable buckling phenomenon is observed in the transition zone of the operating diagram because a condition occurs once per revolution where a displacement sufficient to cause buckling is imposed on the leaves loaded in compression. Symmetrical leaves are free to accommodate this displacement by buckling either way and oscillation once per revolution between the alternative shapes causes the bi-stable buckling motion.

Such a bi-stable buckling motion, i.e. the change of displacement of the central part of each leaf from being displaced axially in one direction from an unstressed position to being displaced axially in the other direction from said position is noisy and can damage the coupling.

It is an object of the invention to provide a coupling which avoids this problem.

According to the invention we provide a coupling of annular shape comprising an even number of fixing portions spaced apart circumferentially around the coupling for connection to two rotary members to be coupled by the coupling and flexible leaves extending lengthwise between each two adjacent fixing portions; characterised in that the coupling is so constructed that the central part of at least each circumferentially alternate leaf will always be displaced axially (as defined above) in the same direction transverse to its length when such leaf is caused to buckle by compressive force(s) acting between the fixing portions at the ends of the leaf.

It is only necessary, in theory, that alternate ones of the leaves are arranged so that they buckle in a pre-determined direction in compression if these can be arranged to be the leaves which will be in compression in use. However if a coupling is to be used reversibly then the central portion of each leaf must buckle in a pre-determined direction when the leaf is longitudinally compressed. It is not necessary that the central parts of all the leaves are displaced in the same direction on buckling, it is only necessary that, for a particular leaf, its central part will always displace in the pre-determined direction when the leaf buckles under compression.

The coupling may be made of laminations of metal, e.g. steel which nest together. Alternatively the coupling may be made of a composite (fibre reinforced plastic) material. In the latter case layers of the material may be formed as pre-pregs and laid up and then moulded.

When the coupling is made of composite material each leaf may comprise a relatively thinner central part and transition portions of increasing thickness between the ends of the central part and the relatively thicker fixing portions as described in our GB Patent Application Number 9803479.6.

Various constructions may be used to ensure that the central parts of the leaves are displaced in a pre-determined direction on compressive buckling of the leaves. Where the coupling is made of composite material and there are transition portions at the ends of each leaf then these may be shaped so as to effect the buckling in the pre-determined direction. Alternatively, or in addition, the central portion of each leaf which is required to be displaced in a pre-determined direction on buckling may be made of two layers of material one of which is stiffer than the other. Each layer may extend over the whole width of the central parts. The central part of the leaf will then displace towards the stiffer layer on buckling. The required difference in stiffness may be effected by selection of specific fibre orientations relative to the axis of the leaf and/or by the use of reinforcing fibres of different modulii.

In another arrangement applicable to both metal and composite couplings the central part of each of those leaves in which the central part is to be displaced in a pre-determined direction on buckling is, in an unstressed state, curved between its ends so that the curved part projects axially in the pre-determined direction in which the central part will be displaced when the leaf buckles under compression.

The radius of curvature of the central part in this case may be between 10 and 500 times the axial thickness of the central part of the leaf. The radial width of the central part of each leaf may be at least 10 times its axial thickness.

All the different ways of effecting the buckling of the leaves in a pre-determined direction have, as a common feature, that the central parts of the leaves, and/or the transitional portions if provided are asymmetrical either in shape or construction with respect to a plane perpendicular to the rotary axis of the coupling and passing through the axial mid points of adjacent fixing portions. This is described in more detail below.

The coupling may be made as a unitary member of composite material or as a number of separate links of either metal or composite material each of which comprises two fixing portions with a leaf extending between them, the fixing portions of adjacent links overlapping where the links are secured to a rotary member to be coupled. The construction makes for ease of servicing.

The invention will now be described by way of example with reference to Figures 2 and 10 of the accompanying drawings, in which:-

Figure 2 is an axial view of a coupling constituting one embodiment of the invention;

Figure 3 is a section on the line III-III of Figure 2;

Figures 4 and 5 are sections similar to Figure 3 of a leaf of second and third embodiments of the invention;

Figure 6 is a detail view of part of the leaf of Figure 5;

Figure 7 is an exploded view of a coupling formed of separate links;

Figure 8 is a section on the line VIII-VIII of Figure 7;

Figure 9 is a view of the coupling of Figure 7 assembled; and

Figure 10 is a section on the line X-X of Figure 9.

Referring to Figures 2 and 3, the coupling is annular with a generally hexagonal external profile having its apices rounded off. It comprises six circumferentially spaced fixing portions 10 which are at the apices of the hexagonal external shape, the fixing portions being joined by six leaves 11.

The fixing portions 10 have apertures 12 for bolted connection to respective rotary members which the coupling is to connect. Such rotary members are usually in the form of three-legged spiders. In use the legs of one spider are connected to alternate ones of the fixing portions while the legs of the other spider on the other side of the coupling are connected to the other three fixing portions. In use the coupling rotates about an axis 14 which is perpendicular to the plane of Figure 1. When the respective rotational axes of the two rotary members are aligned with one another (i.e. at an installed angle of 0°) then axis 14 of the coupling is also coincident with the axes of rotation of the rotary members.

As shown the coupling is a unitary member made of composite material comprising a number of laminae suitably arranged with appropriate fibre orientations and dispositions to suit the conditions the coupling is required to endure in use. As seen in Figure 2, the central parts 11a of the leaves 11 are relatively thin in the direction axially of the coupling so that they are able to bend to accommodate angular misalignment between the axes of the rotary members the coupling is to couple.

The fixing portions 10 are substantially thicker than the central parts 11a of the leaves 11. At each end of each leaf 11 there is a tapering transitional portion 13 extending between the central part and the thicker fixing portion 10. Such increase in thickness may be obtained by the provision of additional laminae and/or filler elements in the vicinity of the fixing portions as described in our Patent Application No. 9803479.6.

As seen in Figure 3, viewed in a direction perpendicular to the rotational axis 14, the central part 11a of a leaf 11 is, when unstressed, curved and offset axially from a plane 14a perpendicular to the rotary axis 14 of the coupling and passing through the axial mid-points of the fixing portions 10. The curving of the central parts 11a has the effect that if the leaves are loaded in compression between the fixing portions they will always buckle in a pre-determined direction i.e. in the direction of the arrow A..

The radius of curvature of the curved central part 11a in Figure 3 can be between 10 and 500 times the axial thickness T of the central part 11a as shown in Figure 3. The radial width W in Figure 2 of the central part of the leaf may be at least 10 times the thickness T.

Various other arrangements may be used for ensuring that, when a leaf buckles, the central part is displaced in a pre-determined direction. Thus the transition portions between the central part and the fixing portions of each leaf may be so shaped as to effect this displacement.

This is shown in Figure 4. The central part of the leaf is shown at 15 and, in an unstressed state, is parallel to a plane 16 perpendicular to the rotary axis 14. There are transitional portions 17 of increasing thickness between the ends 18 of the central part and the fixing portions 19 which have apertures 20. The transition portions are offset to one side of the plane 16 and this has the effect of causing the central part 15 always to buckle in the direction of the arrow A when there is sufficient compressive force along the leaf between the fixing portions 19.

In another arrangement, the central part of each leaf may be made of at least two layers, one of which is stiffer than the other so that when the leaf buckles the central part is always displaced towards the stiffer layer.

In this arrangement the reinforcing fibres in the composite material may be, for example, parallel to the length of the central portion in the stiffer layer and at an angle of $\pm 30^{\circ}$ to the length in the less stiff layer. These angles are only examples. As mentioned above in another arrangement the fibres in the different layers may have different modulii and/or may be laid up at different angles.

This is shown in Figures 5 and 6. The central part of a leaf is indicated at 21 and has ends 22. Transitional portions 23 of increasing thickness extend between the ends 22 and the fixing portions 24. The central part 21 is, in its unstressed state, parallel to a plane 25 perpendicular to the rotary axis 14 through the axial mid-points of the fixing portions. Figure 6 shows the central part as being made of two layers 26 and 27 of composite material. The layer 27 is stiffer than the layer 26 so that the layer 27 has a higher resistance to lengthwise compression than the layer 26. Due to the difference in stiffness of the layers 26 and 27 the central part 21 of the leaf will always buckle in the direction of the arrow A in Figure 5 when sufficient compressive force is applied to the leaf between the fixing portions 24.

As described above the coupling is a unitary member of composite material. However it may be made of a number of discrete links each link comprising two fixing portions, one at each end, and a leaf between the fixing portions. Such an arrangement is shown in Figures 7 to 10.

Referring to these figures the coupling is made of six discrete links 30. Each link comprises a central part 31 which is comparatively thin and two fixing portions 32 which are apertured at 33. As will be seen from Figures 7 and 8 the thickness T of the central part of each leaf is considerably less than the width W of the central part. As described in relation to Figure 3 there are transitional portions 34 of increasing thickness between the ends of the central part and the fixing portions. The links 30 are identical and are assembled into an annular coupling as shown in Figures 9 and 10. The links are assembled into a hexagonal shape as shown in Figure 9 and as shown in Figure 10 the fixing portions 32 of adjacent links overlap, the apertures 33 in the overlapping fixing portions are in alignment and the links are connected together by bolts passing through the aligned apertures 33 which also serve to connect the links to the rotary members which the coupling is to connect.

The links will be constructed so that the central parts of the leaves between the fixing portions will buckle in a pre-determined direction when a compressive force is applied between the fixing portions 32 of the links. As shown in Figures 7 to 10, the construction consists of two layers of different stiffnesses as described in relation to Figures 5 and 6. However each link could be constructed so that the central part of the leaf portion is curved as shown in Figures 2 and 3 or so that the transition portion between the central part and the fixing portion is offset as shown and described in relation to Figure 4.

There is described above a number of different ways in which the leaves of the coupling can be made to buckle in a pre-determined direction when subjected to a compressive force between the fixing portions at the ends of the leaf. What the described embodiments have in common is that the central portions of the leaves and/or the transitional portions if provided are asymmetrical with respect to a plane perpendicular to the rotary axis of the coupling and passing through the axial mid-points of the fixing portions at the ends of the leaf.

The asymmetry may be asymmetry of shape as shown in Figures 2 and 3 with the central part 11a of each leaf being curved and offset relative to the plane 14a or as shown in Figure 4 where the transitional portions 17 are offset from the plane 16.

Alternatively or in addition the asymmetry may be of construction as in Figures 5 and 6 where the layers 26 and 27 are of different stiffnesses.

It is to be understood that if desired only those leaves which are going to be in compression in use may be designed so that the central part displaces in a pre-determined direction when compressed and that it is not necessary that the central parts of every leaf are displaced in the same direction relative to the coupling.

Since in all the above described constructions the central parts of the leaves will deflect only in a pre-determined direction when sufficient compressive force is exerted between the fixing portions at the ends of the leaf there will be no bi-stable buckling as described in relation to the prior art couplings. Once sufficient compressive force is applied to the leaf between the fixing portions it will deflect in only the pre-determined direction and it will remain deflected in that direction during rotation irrespective of the angular misalignment of the rotary axis of the rotary members being coupled by the coupling. This therefore overcomes the problems of noise and damage caused by the bi-stable buckling of the present couplings.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

Claims

1. A flexible annular coupling comprising an even number of fixing portions spaced apart circumferentially around the coupling for connection to two rotary members to be coupled by the coupling and a flexible leaf extending lengthwise between each two adjacent fixing portions; characterised in that the coupling is so constructed that the central part of at least each circumferentially alternate leaf will always be displaced axially (as hereinbefore defined) in the same pre-determined direction transverse to its length when such leaf is caused to buckle by compressive force(s) acting between the fixing portions at the ends of the leaf.

2. A coupling according to Claim 1 so constructed that the central part of each leaf will always be displaced in the same pre-determined direction transverse to its length when such leaf is caused to buckle by compressive force(s) acting between the fixing portions at the ends of the leaf.

3. A coupling according to Claim 1 or Claim 2 wherein the central part of each of those leaves whose central part is displaced in said pre-determined direction when the leaf buckles under compressive forces is, when in an unstressed state, curved between its ends so that it is offset to one side of a plane perpendicular to the rotary axis of the coupling and passing through the axial mid-points of the adjacent fixing portions.

4. A coupling according to Claim 3 wherein the radius of curvature of each of said central part is between ten and five hundred times the thickness of the central part of the leaf measured axially of the coupling.

5. A coupling according to any preceding claim made of laminations of metal, e.g. steel.

6. A coupling according to any of Claims 1 to 4 made of composite (fibre reinforced plastic) material.

7. A coupling according to Claim 6 wherein each leaf comprises a relatively thinner central part and transition portions of increasing thickness between the ends of the central part and the relatively thicker fixing portions.

8. A coupling according to Claim 6 wherein the transition portions are so shaped as to effect the displacement in said pre-determined direction of the central parts of those leaves in which this occurs when the latter buckle under a compressive force between the fixing portions.

9. A coupling according to Claim 8 wherein the transitional portions are offset to one side of a plane perpendicular to the rotary axis of the coupling and passing through the axial mid-points of the adjacent fixing portions.

10. A coupling according to any of Claims 6 to 9 wherein the central part has two layers extending generally perpendicular to the rotary axis of the coupling, one layer having a higher stiffness to resist lengthwise compression of the leaf than the other layer.

11. A coupling according to any preceding claim in which the width of the central part of each leaf measured radially of the coupling is at least ten times its thickness measured axially of the coupling.

12. A coupling according to any preceding claim and which comprises a number of discrete links, each link including a fixing portion at each end a leaf extending between the fixing portions.

13. A coupling as claimed in Claim 1 or Claim 2 in which each leaf the central part of which is required to be displaced in the pre-determined direction is asymmetrical in shape and/or construction with respect to a plane perpendicular to the rotary axis of the coupling and passing through the axial mid-points of the fixing portions at the ends of the leaf.

14. A flexible coupling substantially as hereinbefore described with reference to Figures 2 and 3 or Figure 4 or Figures 5 and 6 or Figures 7 to 10 of the accompanying drawings.

15. Any novel feature or novel combination of features described herein and/or shown in Figures 2 and 3 or Figure 4 or Figures 5 and 6 or Figures 7 to 10 of the accompanying drawings.

INVESTOR IN PEOPLE

Application No: GB 9821491.9
Claims searched: 1 to 14
Examiner: John Twin
Date of search: 18 March 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): F2U (U547, U558)

Int Cl (Ed.6): F16D 3/50, 3/56, 3/58, 3/60, 3/70, 3/72, 3/74, 3/78, 3/79

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2322428 A	(GKN)	
A	GB 1352231	(Jorn) - see eg figs. 2, 5	
X	US 5286231	(Zilberman) - see eg fig.2; column 1, line 63 to column 2, line 68	1
A	US 4768992	(Zurn) - see eg fig.8	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		