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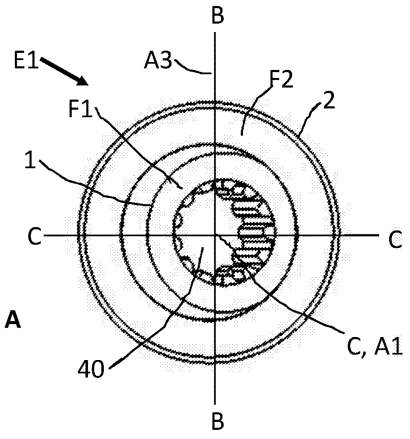
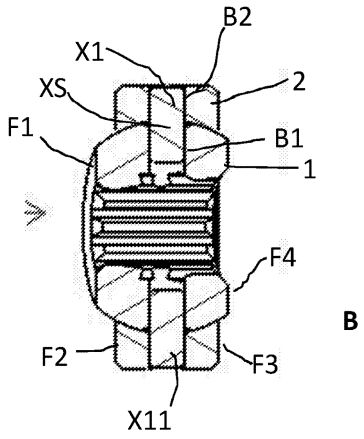
(54) Title of the Invention: **Coupling**
Abstract Title: **Coupling having inner and outer members each with complementary spherical periphery, having an axle arrangement for transmitting torsional loads**

(57) A coupling comprises an inner member 1 having an outer convex spherical periphery S1 centred about a central point C. The inner member has a torsional axis A1 extending through the central point. An outer ring 2 has an inner concave spherical complementary to the outer periphery of the inner member. The spherical surfaces of the inner and outer members co-act to transmit radial loads therebetween and to transmit loads acting along the torsional axis therebetween. An axle arrangement X1, X11 extends radially of the central point C and couples the inner member 1 and outer ring 2 for transmitting torsional load from one to the other. The inner member and outer ring are rotatable one relative to the other about the said central point in a direction constrained by the axle arrangement. The coupling may have additional members (3, 4 & 5, fig 7) and a coupling arrangement (66, 67, fig 6) may connect two couplings.

Figure 2 Half Stud





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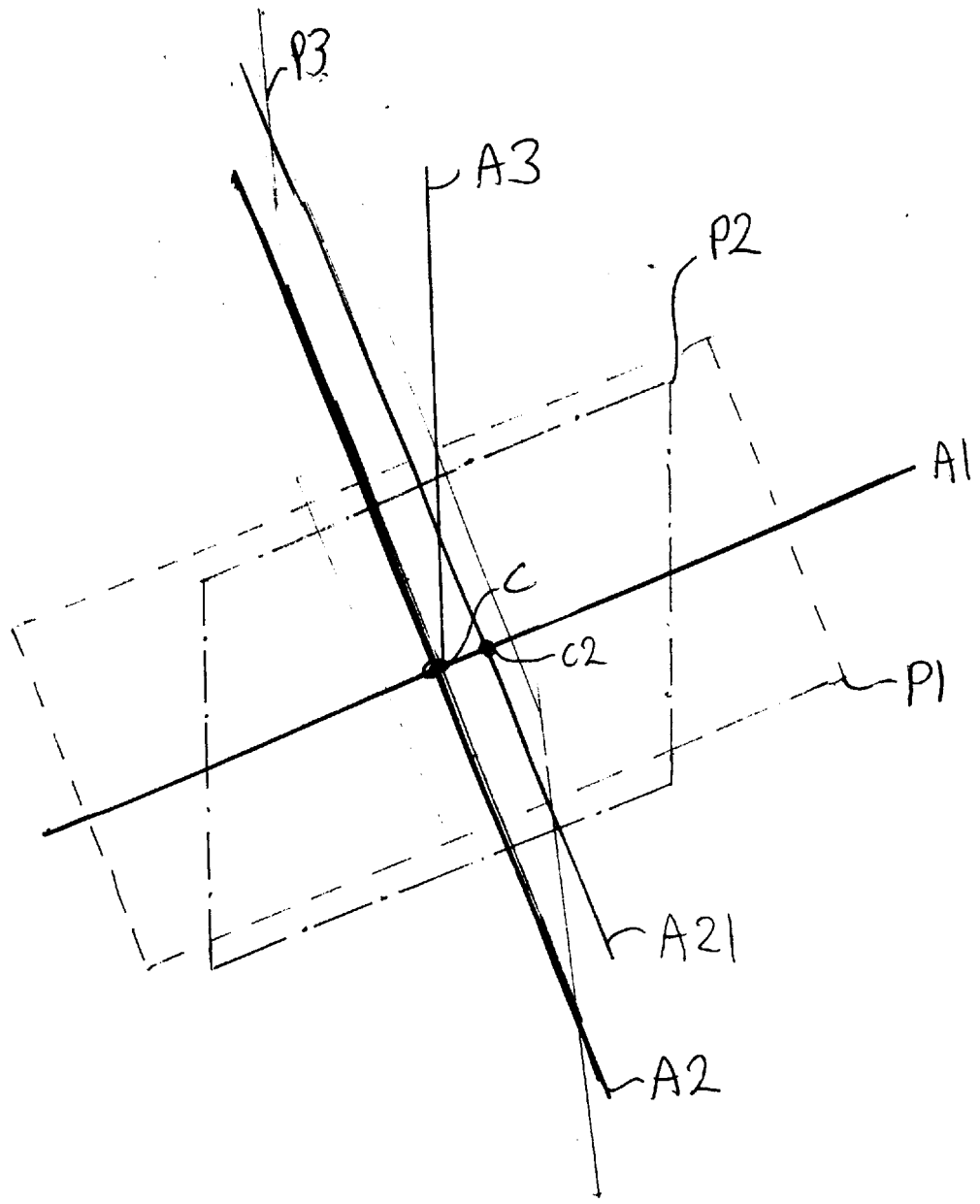


Figure 1

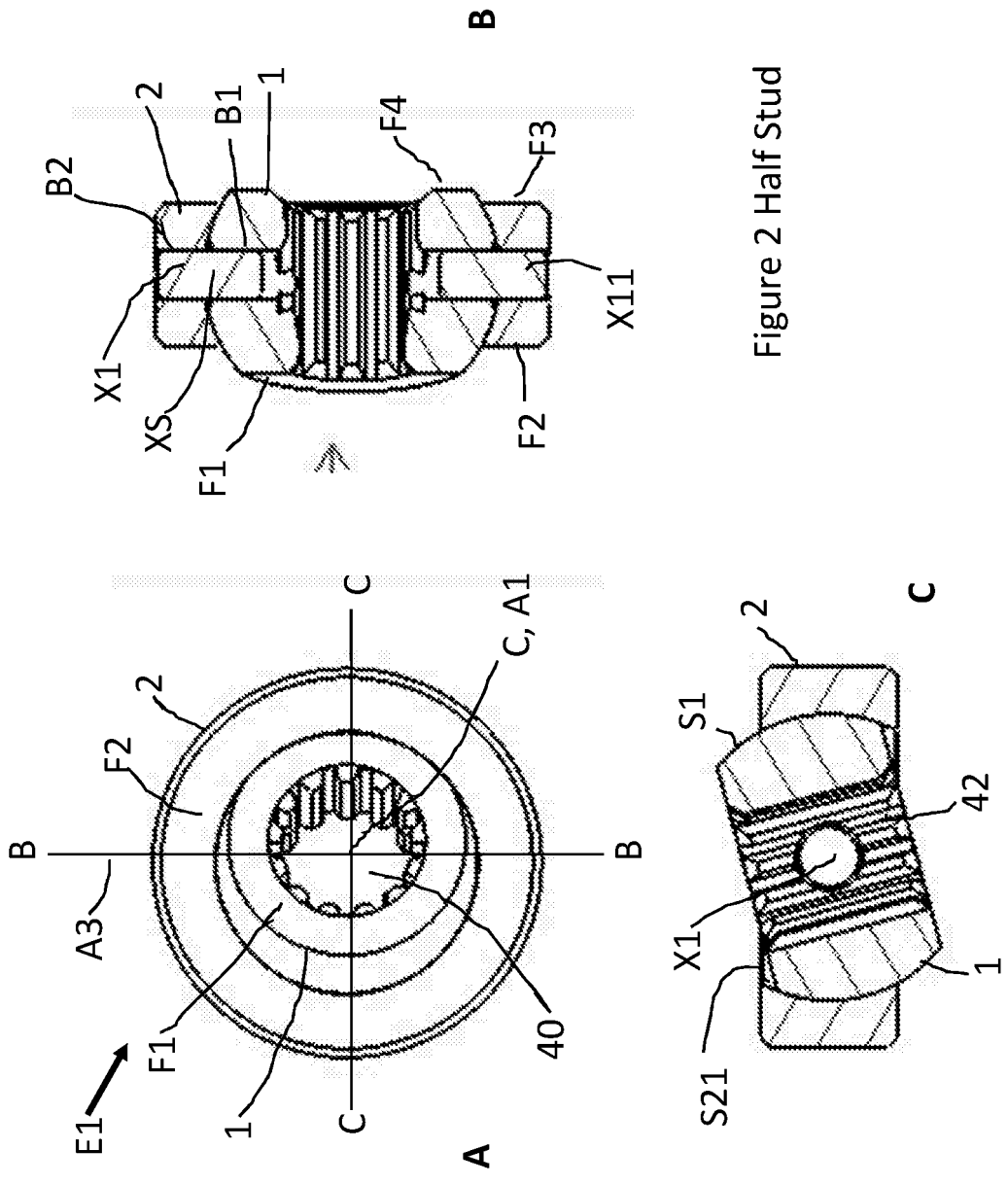
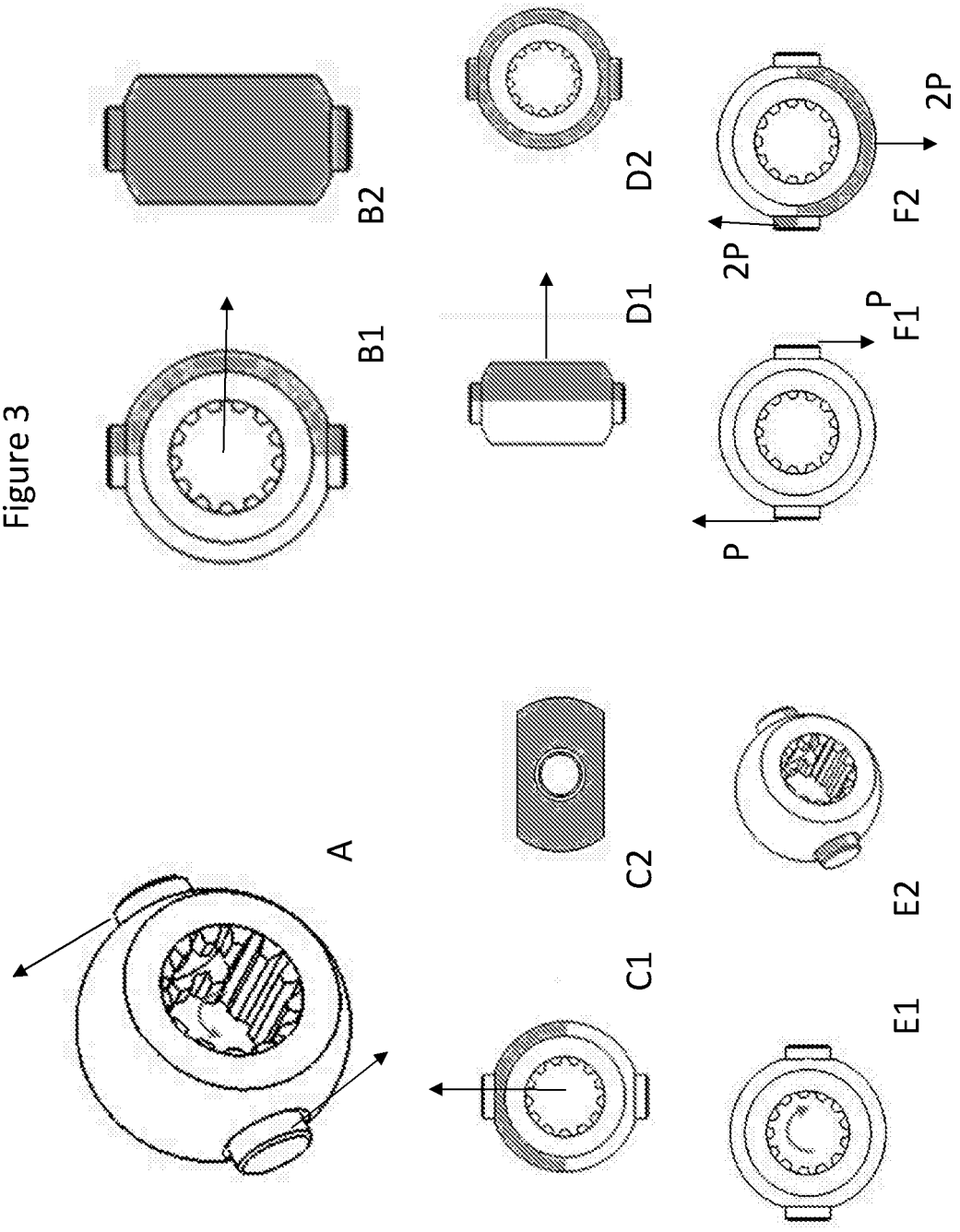
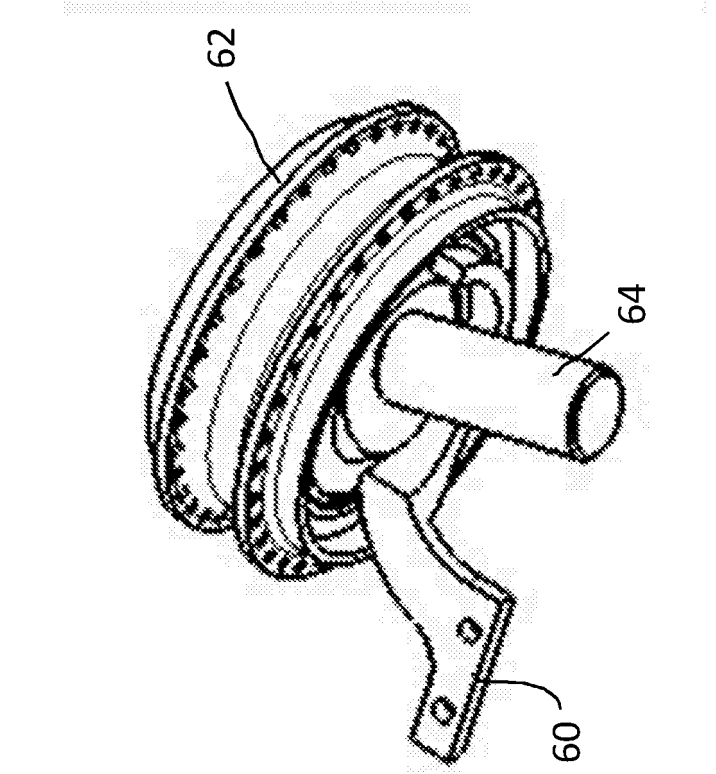


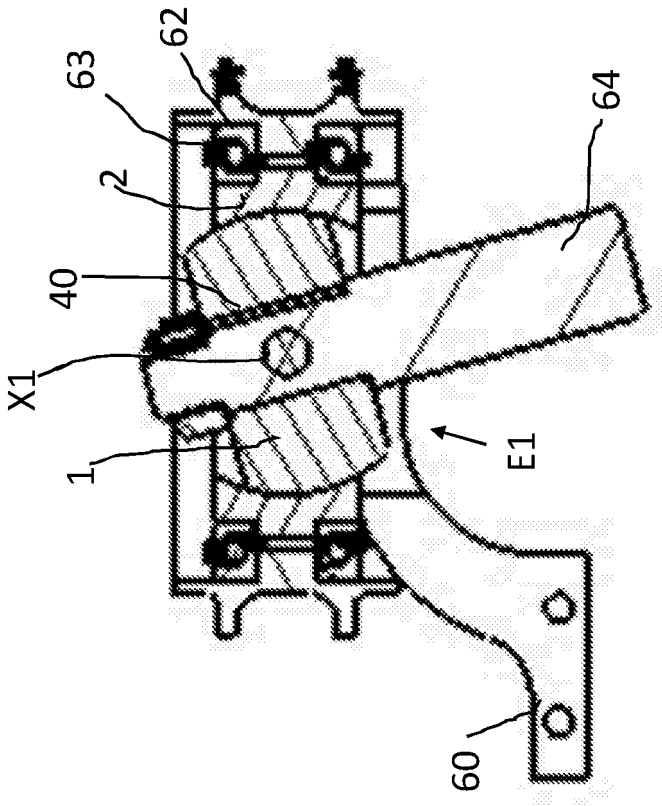
Figure 2 Half Stud

Figure 3





A



B

Figure 4
Steering mechanism

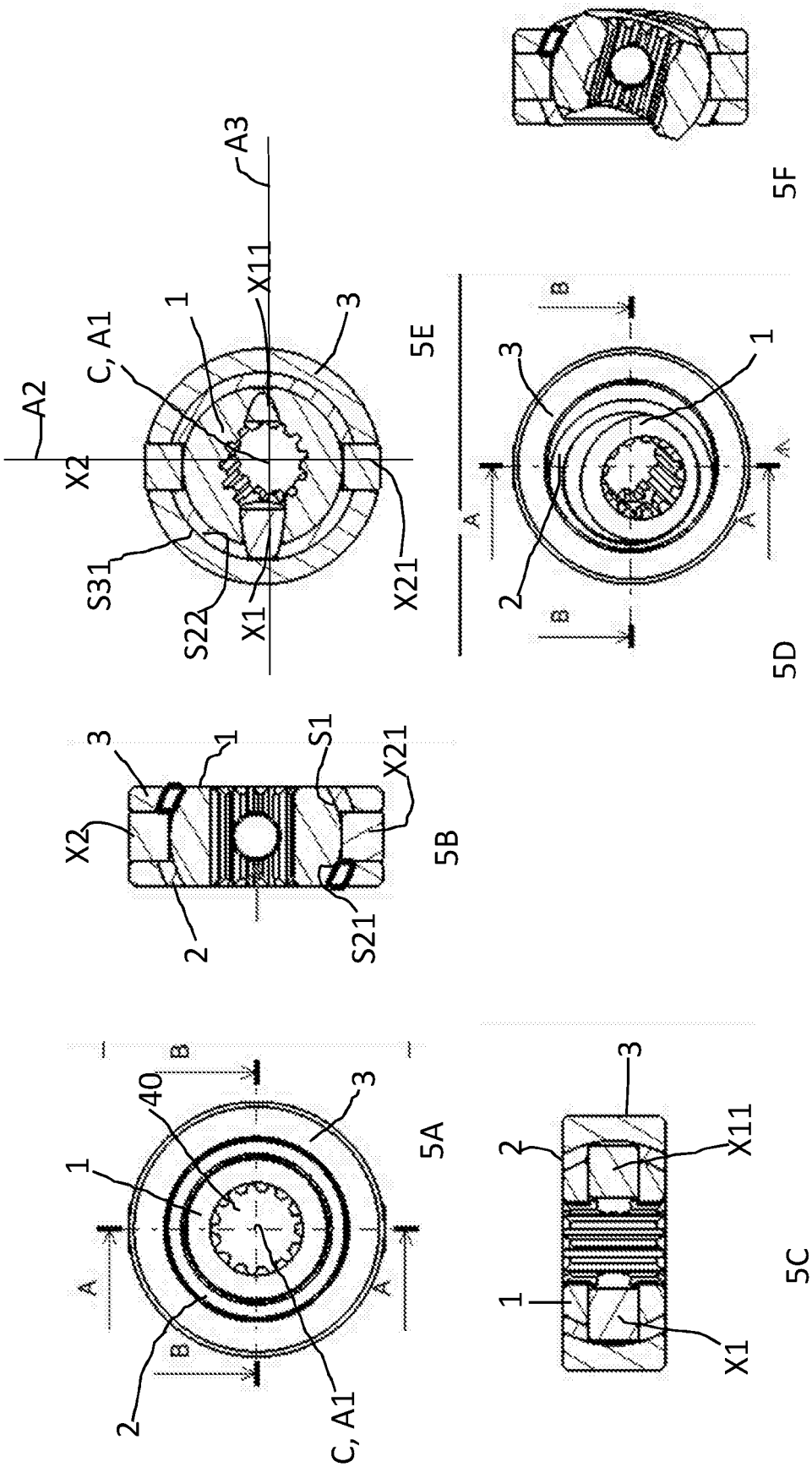
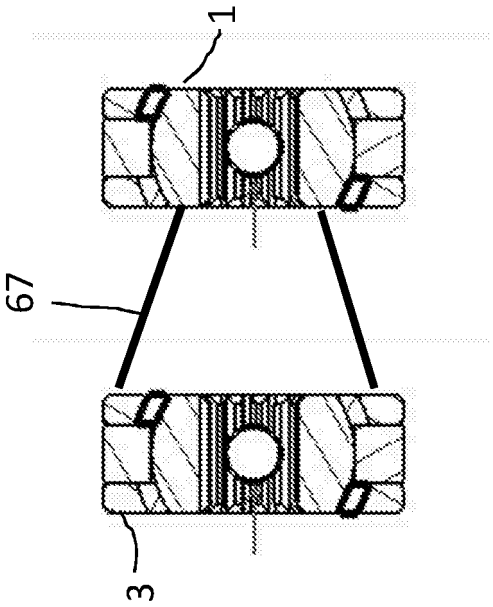

A3
A2
X2
C, A1
1
X11
3
S31
S22
X1
X21
5E
5F
B
A
2
5D
3
S1
X21
X2
2
S21
5B
40
1
3
A
B
2
C, A1
5A
3
2
X11
1
X1
5C

Figure 5



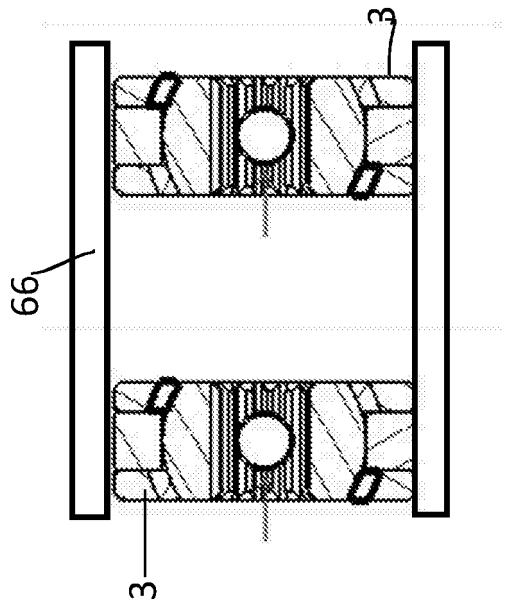


Figure 6
Series coupled

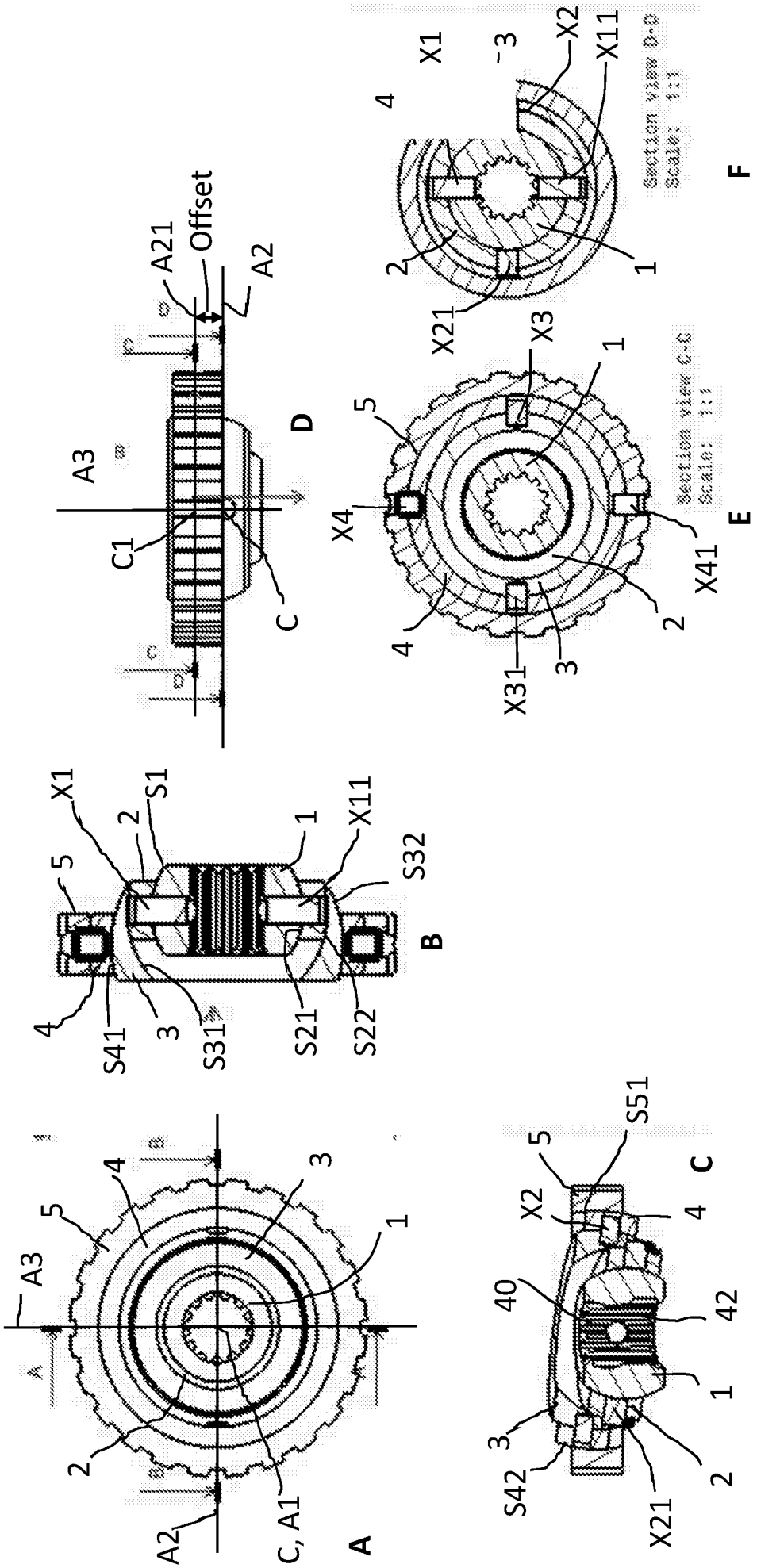
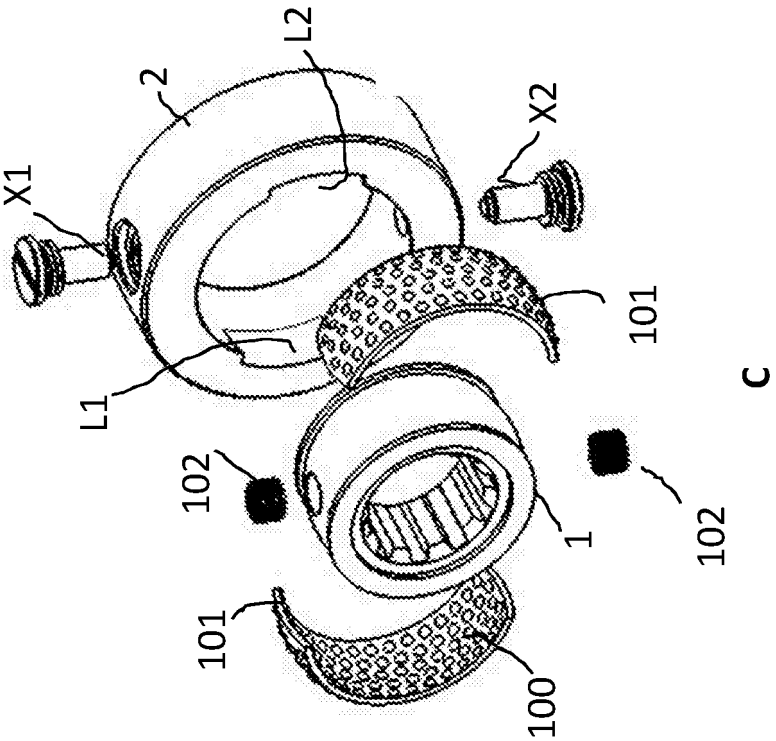
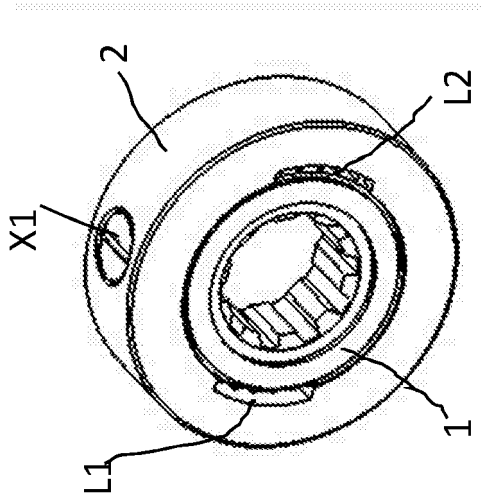


Figure 7 5 ring stud





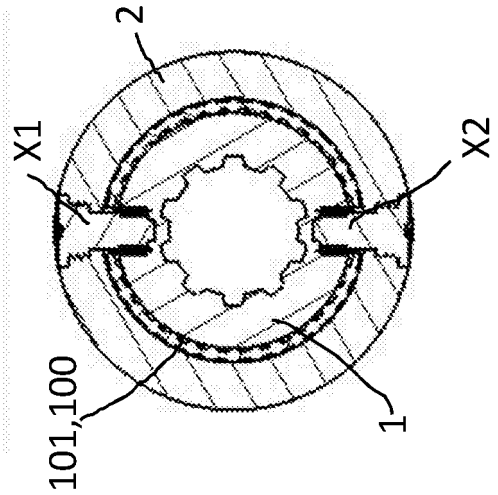


Figure 8 Rolling element Bearings

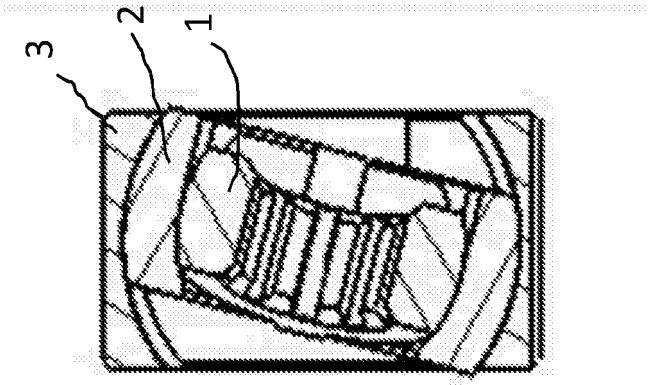


Figure 10

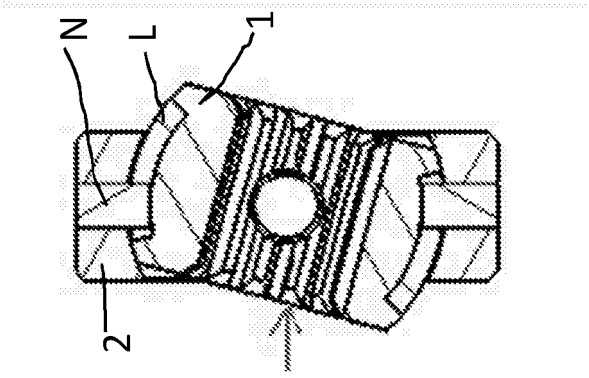


Figure 9

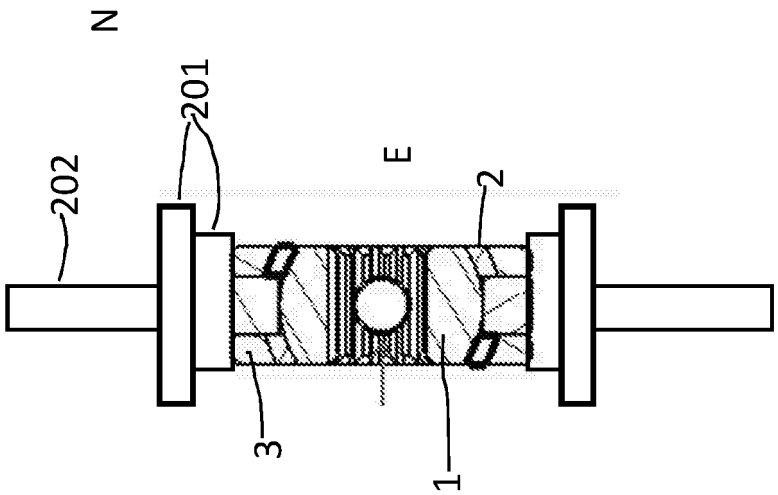
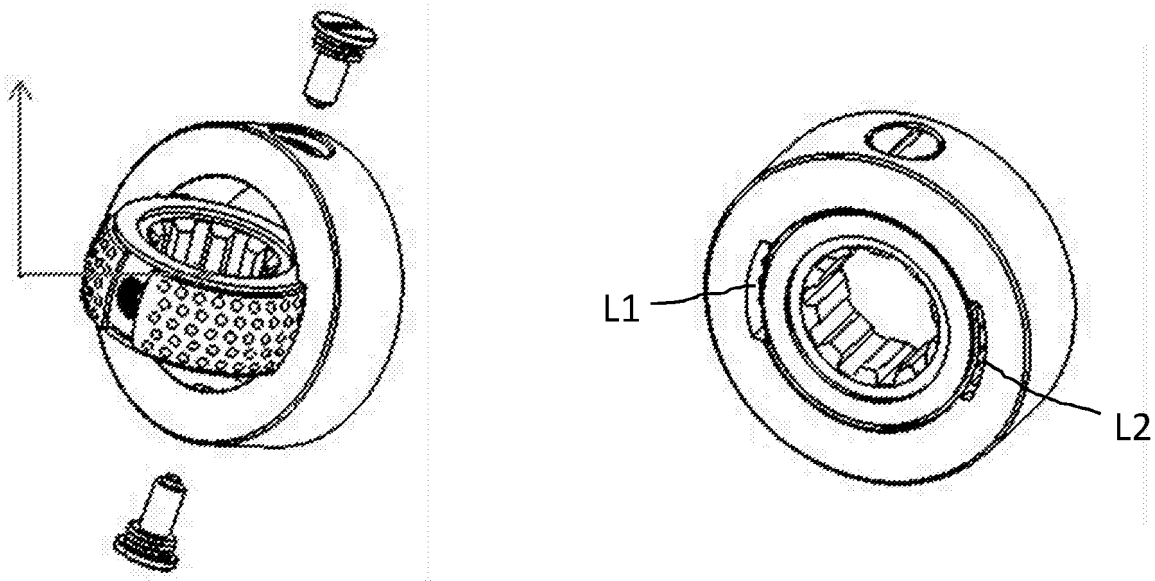


Figure 11 coupling mounted in bearing



A **B**

Figure 12 Loading slots

Coupling

Technical Field

The present invention relates to a coupling.

Background

Mechanical couplings are well known. Examples include couplings for coupling angularly misaligned shafts, universal joints, constant velocity joints, couplings for coupling a drive shaft to a driven shaft, couplings for connecting a torque shaft to a structural element of for example a suspension system.

Summary

According to one aspect of the present invention, there is provided a coupling comprising a first, inner, member having an outer convex spherical periphery centred about a central point, a torsional axis extending through the central point, a second, outer, member in the form of a ring having an inner concave spherical periphery centred about the central point and complementary to the outer periphery of the inner member and arranged to co-act with the inner member to transmit radial loads therebetween and to transmit loads acting along the torsional axis therebetween, an axle arrangement extending radially of the central point and coupling the first and second members for transmitting torsional load from one of the members to the other, the first and second members being constrained by the axle arrangement to be rotatable one relative to the other about the axle arrangement.

The axle arrangement carries torque and the spherical surfaces of the first and second members carry axial and radial loads. Most of any axial load is carried by the spherical surfaces. The axle arrangement may also carry some of the axial load. Thus radial loads are separated from torsional and axial loads. In an embodiment, the axle arrangement is configured to not transmit radial loads between the members coupled thereby so that radial loads are not carried by the axles. Thus radial loads are carried mostly or wholly by the spherical surfaces.

For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings, in which:

Brief Description of the Drawings

Figure 1 illustrates a reference frame of operation of couplings according to embodiments of the invention;

Figures 2A to 2C show an example of a coupling according to the invention, of which Figure 2A is an isometric axial view with the elements of the coupling un-aligned, Figure 2B is a cross-sectional view line B-B of Figure 2A and Figure 2C is a cross-sectional view along line C-C of Figure 2A;

Figures 3A to 3F2 are loading diagrams;

Figures 4A and 4B show a hub centre steering mechanism including an example of a coupling according to Figure 2, of which Figure 4A is an isometric view and Figure 4B is a cross-sectional view.;

Figures 5A to 5F show another example of a coupling according to the invention, of which Figure 5A is an axial view along axis A1 of Figure 1, Figure 5B is a cross-sectional view along plane A-A in Figure 5A, Figure 5C is a cross-sectional view along plane B-B in Figure 5A, Figure 5D is an axial view showing the elements of the coupling un-aligned, Figure 5E is an axial cross-sectional view of the coupling of n Figure 5D and Figure 5F is a cross sectional view along plane A-A of Figure 5D;

Figures 6A and 6B are cross-sectional views of a pair of the couplings of Figure 5 connected together;

Figures 7A to 7F show a further example of a coupling according to the invention, of which Figure 7A is an axial view along axis A1 of Figure 1, Figure 7B is a cross-sectional view along plane A-A in Figure 7A, and Figure 7C is a cross-sectional view on plane B-B of Figure 7A, Figure 7D is a side view; Figure 7E is a cross-sectional view along plane C-C of Figure 7D; and Figure 7F is a side cross-sectional view of the coupling along plane D-D of Figure 7D;

Figures 8A, 8B and 8C show bearings on one representative member of a coupling according to the invention, in which Figure 8A is an isometric view of the coupling, and Figure 8B is a cross sectional axial view, and Figure 8C is an exploded view;

Figure 9 shows means for limiting relative rotation of elements of a coupling according to the invention;

Figure 10 is a cross-sectional view of a modification which may be applied to couplings in accordance with the invention;

Figure 11 is across-sectional view of a representative coupling in accordance with the invention within a bearing; and

Figures 12A and 12B illustrate a way of assembling the coupling of Figure 2.

Detailed Description

Uses of the Couplings

Couplings according to various embodiments the present invention described hereinafter may be used for coupling any two structural elements that must be coupled with at least two rotational degrees of freedom. Some examples are useful as 'structural static couplings' coupling an element to a fixed structure. Other examples are useful as rotational 'flexible couplings' coupling two rotational elements. By way of example, amongst other possibilities, various couplings according to the invention may be used to couple angularly misaligned shafts, as universal joints, constant velocity joints, couplings for coupling a drive shaft to a driven shaft, or as couplings for connecting steered hub to a fixed structural element such as a suspension arm in a suspension system.

Examples of couplings will now be described. Each of these examples is designed to couple one shaft, for example a drive shaft to another shaft, for example a driven shaft, the shafts being removably connected to the coupling. Other examples having one or both shafts fixed to the coupling will be described hereinbelow. Other examples which connect to a static structural element will be described hereinbelow.

Reference Frame-Figure 1

Examples of the invention will be described in relation to a reference frame as shown in Figure 1.

The reference frame has a first axis A1 defining an axial direction. A second axis A2 defining an axis of rotation is perpendicular to the first axis A1. At the intersection of the first and second axes is a central point C of concentric spherical surfaces of concentric members of the couplings. The first and second axes and the

central point lie in first plane P1 and the first axis and central point lie in a second plane P2 perpendicular to the first plane. Plane P2 is coincident with, and parallel to, the first axis A1. A third plane P3 through the centre point C is perpendicular to the other planes. A third axis defining an axis of rotation lies in the third plane and passes through the central point C.

In examples of couplings described hereinbelow, the first axis A1 is a torsional axis on which, amongst other examples, a drive shaft or driven shaft is connected to the coupling and the second A2 and third A3 axes are axes of relative rotation of members of the couplings.

In further examples, couplings have some elements centred on the central point C and other elements centred on a further central point C2 offset from C along the first axis A1. The offset of C2 from C may be slight, for example a fraction of a millimetre.

First example of a coupling-Figures 2A to 2D

Referring to Figure 2, a coupling according to a first example E1 of the invention comprises a first, inner, member 1 in the form of a ring centred on the central point C on the first axis. The inner ring 1 has an outer peripheral surface S1 which is convexly spherical centred on the central point C on the first axis. The inner ring 1 has a central cylindrical bore 40 which in this example has splines 42 for engaging a correspondingly splined shaft.

A second, outer, member 2 in the form of a ring has an inner peripheral surface S21 which is convexly spherical complementary to the outer surface S1 of the inner ring 1. The concave spherical surface S21 is centred on the same central point C on the axis as the spherical surface of the inner ring. In this example the inner spherical surface S21 of the outer ring and the outer spherical surface S1 of the inner ring 1 are contiguous plain bearing surfaces.

In the example of Figure 2, the inner and outer rings are coupled by an axle arrangement comprising a diametrically opposed pair of axles X1 and X11 which are on a diameter through the central point C, in this case on axis A3, although equally it could be along axis A2. The pair of axles constrain the inner and outer rings to be rotatable, one relative to the other, about the second axis A2 of rotation through the central point and perpendicular to the first axis A1.

Referring to Figure 2, each of the axles X1 and X2 comprises an axle shaft XS fixed in a bore B2 in the outer ring 2 and extending into a bore B1 in the inner member 1 in which it is free to rotate. The shafts are arranged so that they do not transmit radial loads between the inner and outer rings. That is done by providing radial clearance between the ends of the axles and the radially adjacent spherical surfaces and by allowing some radial freedom of movement in the bore B1 between the shaft XS and the inner member 1.

The shafts may be fixed in the outer ring by an interference fit or be otherwise fixed by for example a cold weld.

A ball or roller bearing arrangement may be provided around the shaft in the bore B1 in the inner member 1.

The axles may take other forms. For example, as shown in Figure 8, the shaft XS may have a head H in a recess in the outer surface of the outer member 2 so as to not protrude above the outer surface and be fixed in the outer member by a screw-threaded engagement in the bore B2 in the outer member.

"Self Retaining" arrangement

The axles retain the inner member 1 axially within the outer member 2. In addition, the spherical surfaces of the inner and outer members co-act to retain the inner member axially within the outer member.

The central point C of the adjacent convex and concave spherical surfaces lies between the axial facing faces F1 and F3 of the inner member 1 and between the faces F2 and F4 of the outer member 2. As a result of that, the periphery of the inner convex spherical surface mid-way between the axially facing faces F1 and F3 is at a greater radius than the periphery of the concave surface of the outer member 2 at the axially facing faces thereof F2 and F4. Thus the inner ring is retained axially in the outer ring over an operational range of rotation of the inner ring about the second axis and/or about the first axis.

Splines

The first and second examples E1 shown in Figure 2 have splines in the central cylindrical bore of inner member 1 for engaging a shaft. Splines (not shown) may

additionally or alternatively be provided on the outer periphery of the outer member 2 for engaging another shaft. The coupling may be allowed to slide relative to the shaft(s) providing an axial degree of freedom.

Form of inner and outer members

The inner and outer members are both rings in the examples of Figure 2. Each is a section of a sphere centred on the central point C at the intersection of the first A1 and second A2 axes.

In another example the inner member 1 may be integral with a structural element, for example a shaft.

Loading

In Figures 3A to 3F2, load bearing paths are shown shaded.

In the first example of Figure 2, the spherical surfaces bear loads acting radially of the first axis A1 and in the direction of the axis A1. The axles X1, X11 transmit torque about the first axis between the inner 1 and outer 2 members. The spherical surfaces of the inner and outer members 1 and 2 provide large bearing surfaces which allow large torques to be carried, unlike spigots and balls that run inside slots or grooves. Furthermore, the coupling contact surface projection is tangential to the torque axis, such that undesirable radial burst forces are not created, unlike balls in grooves. The coupling efficiently separates the translational (axial and radial) and torsional load paths. Radial and axial loads are carried by the spherical contact surfaces. Torsion is only carried by the torque load path. There is a clearance between the radially facing surface of an axle and the radially facing surface of the bore into which it projects so the axles do not transmit radial loads between the rings. The axles also carry axial load as shown in loading diagram.

Figure 3A shows the axles X1 and X11 providing a torque path. Figures 3B1 and 3B2 show radial and bearing pressure for a load perpendicular to the axles. Figures 3C1 and 3C2 radial and bearing pressure for a load along the axles. Figures 3D1 and 3D2 show axial load and bearing pressure.

Figures 3E1 and 3E2 show the axles bearing a torque load.

Figure 3F2 shows how a single axle is able to carry the torsion load in combination with the spherical contact surface; however this is less efficient than having two diametrically opposed axles on each ring as shown in Figure 3F1. Figure 3F2 also shows that an alternative 'fail-safe' load path is provided if one of the axles should fail. As shown in Figure 3F2 a single axle is able to carry the torsional load in combination with the spherical bearing surfaces S1 and S21. This provides redundancy in case one of two projections fails. The load on an axle may be 2P and the corresponding reaction force is carried by the spherical surface of half of the ring.

The coupling efficiently separates the translational (axial and radial) and torsional load paths.

Second Example of a Coupling

Referring to Figure 2, the first example E1 as described above has two diametrically opposite axles which share loads on the coupling. In this second example, only one axle is present on the axis A3. Such an example is operable under light loads.

Uses of Coupling

The first and second examples have static applications such as Hub Centre Steering as will be described with reference to Figure 4.

In one use of the first and second examples of the coupling, rotation of the shaft about the first axis is transmitted from the inner member 1 by the axles to the outer member 2 which also rotates. The outer member may be connected to another shaft. In another use, one of the members, e.g. the outer member, is fixed and static torque is transmitted from the inner member to the outer member.

Steering Mechanism- Figure 4

One illustrative use of the first or second example of the coupling of Figure 2 is in a steering mechanism of a vehicle. In the example of Figure 4 a steered hub 62 of a wheel is supported by a support member 64 which in this example is a suspension arm. The coupling E1 couples the suspension arm 64 to the steered hub 62.

The arm 64 is engaged, for example by splines, in the central bore 40 of the inner ring 1 of the coupling. The axles(s) X1, X11 (only X1 shown) allow the outer ring

2 to rotate about one axis (the steering axis) relative to the inner ring 1 and arm 64. The outer ring 2 supports the wheel 62 which is free to rotate on bearings 63. A steering arm 60 is fixed to the outer ring 2 to rotate it relative to the inner ring and arm 64.

In this example the axle(s) X1, X11 provide support to allow relative rotation but do not drive the wheel 62.

Third Example of a Coupling - Figure 5

The coupling of Figure 5 comprises a first, inner member 1 in the form of a ring centred on a first axis, the inner ring 1 having an outer peripheral surface S1 which is convexly spherical centred on the point C on the axis A1. The inner ring 1 has a central cylindrical bore 40 which in this example has splines for engaging a correspondingly splined shaft.

A second, intermediate, member 2 in the form of a ring has an inner peripheral surface S21 which is concavely spherical complementary to the outer surface S1 of the inner member 1. In this example the inner spherical surface S21 of the intermediate member and the outer spherical surface S1 of the inner member 1 are contiguous plain bearing surfaces.

A first pair of diametrically opposed second axles X1 and X11 extend radially of, the first axis A1 on the third axis A3 to couple the first member 1 to the intermediate member 2. The first and second axles constrain the first and second members to rotate one relative to the other about the third axis A3.

The intermediate member 2 has an outer periphery S22 which is convexly spherical. A third member 3 in the form of a ring has an inner peripheral surface S31 which is concavely spherical complementary to the outer surface S22 of the intermediate member 2. In this example the inner spherical surface S31 of the third member and the outer spherical surface S22 of the intermediate member 2 are contiguous plain bearing surfaces.

A second pair of diametrically opposed axles X2 and X21 extend radially of, the first axis A1 along the second axis A2 perpendicular to the third axis A3 to couple the second member 2 to the outer member 3. The axles X2 and X21 constrain the intermediate 2 and outer 3 members to be rotatable one relative to the other about the second axis A2 of rotation (see Figure 1) through the centre point C, and perpendicular

to the first axis A1 and perpendicular to the third axis A3. The second pair of axles allow relative rotation of the second and third members independently of the first and second members.

In similar manner as described with reference to figure 3, the spherical surfaces S1, S21, S22 and S31 bear loads acting radially of the axis A1 and in the direction of the axis A1. The axles transmit torque between the first (inner) 1, second (intermediate) 2, and third (outermost) 3, members.

The inner member 1 is retained in the intermediate member 2, and the intermediate member 2 is retained in the outer member 3 in the same way that the inner member 1 of the first or second example is retained in the outer member 2.

A first shaft or other structural element may be engaged in the central bore in the inner ring 1 and a second shaft or other structural element may be engaged with the outer member 3. For that purpose the outer member may be fixed to or integral with a flange (not shown) or it may comprise other means, for example splines, for coupling to a structural element.

One illustrative use of the third example of the couplings of Figure 5 is as a universal joint.

The coupling allows angular misalignment of the shafts by virtue of the relative rotation of the inner 1 and outer 3 members about the second axis.

Fourth Example of a Coupling – Figure 6

Figure 6A shows a coupling arrangement comprising two couplings of Figure 6 connected together by a connecting structure 66. The structure rigidly connects the two couplings. In Figure 6A it connects the third, outer, members 3 of the couplings. In the example of Figure 6A the connecting structure is a tube coupling the outer members. In another example, instead of the tube, the outer member 3 of one coupling is connected by a connecting structure 67 to the inner member 1 of the other as shown for example in Figure 6B.

One illustrative use of the coupling of Figure 6A using the coupling of Figure 5 is as an approximation to a double Cardan joint if the axle pairs of one of the couplings are non-orthogonal to corresponding axle pairs of the other.

One illustrative use of such a coupling using the first or second example of Figure 2 is a crank handle if the axles of the two couplings are in the same orientation. In other examples the axle(s) of one coupling are orthogonal to the projection(s) of the other.

One of the couplings may be free to move axially in the tube 66.

Fifth Example of a Coupling- Figure 7

The coupling of Figure 7 comprises a first, inner, member 1 in the form of a ring centred on the central point C on the first axis A1, the inner ring 1 having an outer peripheral surface S1 which is convexly spherical centred on the central point C on the first axis. The inner ring 1 has a central cylindrical bore 40 which in this example has splines 42 for engaging a correspondingly splined shaft.

A second member 2 in the form of a ring has an inner peripheral surface S21 which is concavely spherical complementary to the outer surface S1 of the first ring 1. In this example the inner spherical surface S21 of the second ring 1 and the outer spherical surface S1 of the first ring 1 are contiguous plain bearing surfaces.

A first pair of diametrically opposed axles X1, X11 extend along the third axis A3 radially of the first axis A1 to couple the first 1 and second 2 members. The first pair of axles constrain the first and second rings to be rotatable one relative to the other about the third axis A3 of rotation through and perpendicular to the first axis A1.

The second ring 2 has an outer periphery S22 which is convexly spherical. A third member 3 in the form of a ring has an inner peripheral surface S31 which is concavely spherical complementary to the outer surface S22 of the second member 2. In this example the inner spherical surface S31 of the third member 3 and the outer spherical surface S22 of the second member 2 are contiguous, plain, bearing surfaces.

A second pair of diametrically opposed axles X2, X21 extend along the second axis A2 radially of the first axis A1 coupling the second and third members 2 and 3. The second axle pair constrain the second 2 and third 3 members to be rotatable one relative to the other about the second axis A2 of rotation through the central point C, and perpendicular to the first axis and perpendicular to the third axis A3. The second pair of axles allow relative rotation of the second and third members independently of the first and second members.

The third member 3 has an outer periphery S32 which is convexly spherical. A fourth member 4 in the form of a ring has an inner peripheral surface S41 which is concavely spherical complementary to the outer surface S32 of the third member 3. In this example the inner spherical surface S41 of the fourth member 4 and the outer spherical surface S32 of the third member 3 are contiguous, plain, bearing surfaces.

A third pair of diametrically opposed axles X3, X31 extend along the second axis A2 radially of the first axis A1 coupling the third and fourth members 3 and 4. The third axle pair constrain the third and fourth members 3 and 4 to be rotatable one relative to the other about the second axis A2 of rotation through the central point C, and perpendicular to the first axis and perpendicular to the third axis A3. They thus constrain the third 3 and fourth 4 members to be rotatable one relative to the other about the second axis A2 of rotation. (It will be noted the third axle pair are coaxial with the second axle pair). The third pair of axles allow relative rotation of the third and fourth members independently of the second and third members.

The fourth member 4 has an outer periphery S42 which is convexly spherical. A fifth member 5 in the form of a ring has an inner peripheral surface S51 which is concavely spherical complementary to the outer surface S42 of the fourth member 4. In this example the inner spherical surface S51 of the fifth member 4 and the outer spherical surface S42 of the fourth member 4 are contiguous, plain, bearing surfaces.

A fourth pair of diametrically opposed axles X4, X41 extend along the third axis A3 radially of the first axis A1 coupling the fourth and fifth members 4 and 5. The fourth axle pair constrain the fourth and fifth members 4 and 5 to be rotatable one relative to the other about the third axis A3 of rotation through the central point C, and perpendicular to the first axis and perpendicular to the second axis A2. They thus constrain the fourth and fifth members to be rotatable one relative to the other about the third axis A3 of rotation. The fourth pair of axles allow relative rotation of the fourth and fifth members independently of the second and third members.

The members are retained in the coupling in the same way as described hereinabove with reference to Figure 2.

The axles X1 to X41 are identical to the axles X1 and X11 of Figure 2.

Offset

Referring to Figure 7D, it has been found that the fourth and fifth members must be offset relative to the first and second members along the axis A1.The offset may be slight. This may be achieved by offsetting the outer spherical surface S32 of the third member 3 axially of the inner spherical surface S31 of the third member 3. Thus referring to Figure 1, the first and second members are centred on central point C and the third and fourth members are centred on point C2.

One illustrative use of the coupling of Figure 7 is as a double Cardan joint.

Bearings- Figure 8

In the examples of Figures 2 to 7, the spherical surfaces are all contiguous, plain, bearing surfaces. Ball, barrel, roller or other rotational bearings may be provided between the adjacent spherical surfaces.

Referring to Figure 8, ball bearings 100 held in one or more cages 101 may be provided at the surface of a member of a coupling. In the example of Figure 8, the balls are held in two ball baskets, which are half spherical pieces, between the axles X, which may be axles X1 and X11 of the inner member 1 or of any other member 2, 3, 4.... Thus the spherical surfaces have rolling elements for carrying radial loads; this radial load path is independent of the torque load being applied. This approach is more efficient than using balls in grooves to carry both the torsion and the radial load.

Rolling element bearings 102 may be mounted on the axles, such that the radial bursting forces associated with conventional balls in grooves are not generated.

Limit to relative rotation of adjacent members Figure 9

The spherical surfaces of adjacent members co-operate to bear radial and axial loads. To ensure that the coupling can bear a desired axial and radial load the spherical surfaces need to overlap sufficiently. Thus in embodiments of the invention, means may be provided to limit the relative rotation of adjacent members. Such limiting means also assists the retention of each inner ring in its associated outer ring. Examples of such limiting means include a stop within the coupling. As shown for example in Figure 9, in one example a fixed pin N projecting from an outer member 2 into a slot L in an inner member 1. It will be appreciated that any other suitable means of limiting relative rotation may be used. In some examples the coupling is supported by a support structure

which limits relative rotation. In others the structural elements coupled by the coupling limit the relative rotation.

Increase range of relative rotation- Figure 10

As shown in Figure 10, to increase the operational range of relative rotation, the outer one 2, or 3 of two adjacent members 1 and 2 or 2 and 3 may be larger in the axial direction than the inner one 1 or 2. Figure 15 shows three rings 1, 2 and 3. The principle of Figure 10 may be applied to any of the pairs of rings of the examples of the invention.

Sixth Example – Figure 11

Referring to Figure 11, any of the first, second, third and fifth examples of a coupling described above may be fixed within a bearing 201 which may be fixed to a fixed structure 202 for example a bulkhead, floor or wall. That allows the coupling to couple to any two structural elements, one each side of the fixed structure 202, that must be coupled with at least two rotational degrees of freedom. For example the fixed structure may be a bulkhead of a vehicle and the coupling couples section of a steering mechanism of the vehicle.

The bearing 201 allows the coupling E of Figure 11 to rotate within the fixed structure 202.

Other Variants

Structural elements fixed to couplings

In an alternative embodiment a structural element such as a shaft is fixed to, or integral with, the first, innermost, member 1 of a coupling. In an alternative embodiment, a structural element such as a shaft is fixed to, or integral with, the outermost, member of a coupling. Structural elements may be fixed to, or integral with, both the innermost and outermost members of a coupling.

Connecting a Coupling to a Structural Element

The examples described above may have splines in the inner ring and or on the outer most peripheral surface of the coupling for connecting the coupling to structural elements to be coupled.

Alternatively any other suitable means of connecting the coupling to structural elements may be used. For example the outer periphery may have screw thread for connecting it to a correspondingly threaded structural element. Likewise the first, inner most member 1 may have a central bore as shown in Figure 2, which is screw threaded. The first member may be integral with a shaft which is screw threaded for connection to another structural element. The outermost member of the coupling may be connected to a structural element by any suitable means.

Making a coupling

For plain bearing surfaces, the mating convex and concave spherical surfaces should match accurately. That requires appropriately precise manufacture of the couplings.

A lining material may be injected between the spherical bearing surfaces. The convex spherical surfaces may be accurately machined. The concave spherical surfaces may be roughly machined to form a rough surface which is also a piece-wise linear approximation to a curved surface also known as cathedraling, and lining material injected between an accurately machined convex surface and the rough concave surface to form an accurately matched concave spherical surface. The convex spherical surface is coated with a release agent before the lining is injected into the coupling.

The lining material may be of plastic. The composition of some of the plastics are not publically known as the suppliers are often commercially sensitive about their compositions. However Delrin is one known product that could be used or PTFE based materials could be used.

Assembling a Coupling Figures 8C, 12A and 12B

Referring to Figures 8C 12A and 12B, and the example of Figure 2, the outer member 2 has two diametrically opposite loading slots L1 and L2. As shown in Figure 8C, the loading slots extend halfway across the width of the outer member 2. The slots are dimensioned so that the diametrically opposite floors of the slots are spaced by the

diameter of the outer surface S1 (including if provided the cages101) of the inner member 1. The width of each slot is equal to or slightly greater than the width of the inner member. The inner member 1 is introduced sideways into the slots as shown in Figure 12A and then rotated into the same plane as the outer member. The axle bore (s) of the inner and outer members are brought into alignment at a suitable stage in the assembly process and the axle shaft(s) are inserted.

Figure 12 shows one option for assembling a coupling. In another option the outer member 2 is formed of two halves (or three or more sections) which are assembled around the inner member 1 and then fixed together. The two halves may be fixed by bolts, welding, fusing, swaging or in any other suitable way.

Materials

Couplings as described above made be of any suitable material. The examples having plain bearing surfaces may be of metal, e.g. high performance steels, brass, bronze, aluminium, titanium etc or of plastic, e.g. nylon, glass filled nylon, acetal, ABS, delirium.

It should be noted that the inner and outer rings 1 and 3 of the coupling of Figure 5 may be connected to respective shafts or other structural members so the middle ring 2 is the only part which moves relative to the other two; this might lead a designer to select brass or bronze for the moving middle ring and steel for the inner and outer rings. The same philosophy could be applied to the other examples of the couplings.

Metal rings may be lubricated by conventional lubricants for example grease. Alternatively, dry lubricant surfaces may be provided such as plastic liners as discussed above. The choice of materials and lubricants depends on the intended use of the coupling.

The above embodiments are to be understood as illustrative examples of the invention. Further embodiments of the invention are envisaged. It is to be understood that any feature described in relation to any one embodiment may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments. Furthermore, equivalents and modifications not described above

may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.

CLAIMS

1. A coupling comprising

a first, inner, member having an outer convex spherical periphery centred about a central point, a torsional axis extending through the central point,

a second, outer, member in the form of a ring having an inner concave spherical periphery centred about the central point and complementary to the outer periphery of the inner member and arranged to co-act with the inner member to transmit radial loads therebetween and to transmit loads acting along the torsional axis therebetween,

an axle arrangement extending radially of the central point and coupling the first and second members for transmitting torsional load from one of the members to the other,

the first and second members being constrained by the axle arrangement to be rotatable one relative to the other about the axle arrangement.

2. A coupling according to claim 1, wherein the axle arrangement comprises a pair of diametrically opposed axles coupling the first and second members.

3. A coupling according to any preceding claim, wherein the first member is a ring having a cylindrical bore centred on the said torsional axis for receiving a shaft.

4. A coupling according to claim 3, wherein the bore has splines for engaging a correspondingly splined shaft.

5. A coupling according to claim 1or 2, comprising a shaft fixed to the first member.

6. A coupling according to any preceding claim, wherein the second member has means for coupling to a structural element.

7. A coupling according to claim 6, wherein the coupling means comprises splines.

8. A coupling according to any preceding claim, wherein the convex and concave spherical surfaces are co-acting bearing surfaces of the coupling are contiguous plain bearing surfaces which bear radial loads of the coupling and which bear loads of the coupling acting along the said torsional axis.

9. A coupling according to any one of claims 1 to 7, further comprising a ball or roller bearing arrangement between the convex and concave spherical surfaces.

10. A coupling according to claim 9, wherein the bearing arrangement between the convex and concave spherical surfaces comprises balls within a cage.

11. A coupling according to any preceding claim, wherein the second member is configured to retain the first member within the coupling.

12. A coupling according to any preceding claim, wherein the said central point is on the said torsional axis between the axially facing sides of the first member and between the axially facing sides of the second member.

13. A coupling according to any preceding claim, wherein one of the inner member and the outer ring is fixed against rotation about the torsional axis.

14. A coupling according to any one of claims 1 to 22, wherein the torsional axis is an axis of rotation and the inner member and the outer ring are free to rotate about the torsional axis.

15. A coupling according to any preceding claim, wherein the second member has an outer periphery which is convexly spherical and further comprising

a third member in the form of a ring having an inner concave spherical periphery centred about the central point and complementary to the outer periphery of the second member and arranged to co-act with the second member to transmit load therebetween,

the second member and third member being coupled by a further axle arrangement perpendicular to the first mentioned axle arrangement independently of the first and second members,

the second member and third member being further rotatable one relative to the other about the said central point in a direction constrained by the further axle arrangement independently of the first and second members.

16. A coupling according to claim 15, wherein the further axle arrangement comprises a pair of diametrically opposed axles.

17. A coupling arrangement comprising two couplings according to any preceding claim connected by a connecting structure.

18. A coupling arrangement according to claim 17, wherein the connecting structure connects the outermost said members of the couplings.

19. A coupling arrangement according to claim 18, wherein one of the couplings is free to move relative to the connecting structure.

20. A coupling according to claim 17, wherein the connecting structure connects the outermost said member of one of the couplings to the inner most said member of the other.

21. A coupling according to claim 15, wherein

the third member has an outer periphery which is convexly spherical about a further central point which is offset from the said first mentioned central point in the direction of the torsional axis and further comprising

a fourth member in the form of a ring having an inner concave spherical periphery centred about the further central point and complementary to the outer periphery of the third member and arranged to co-act with the third member to transmit load therebetween, and

another axle arrangement perpendicular to the first mentioned axle arrangement coupling the third and fourth members independently of the first, second and third members,

the third member and fourth member being further rotatable one relative to the other about the said further central point in a direction constrained by the said another axle arrangement independently of the first, second and third members; and wherein

the fourth member has an outer periphery which is convexly spherical about the further central point which is offset from the said first mentioned central point in the direction of the torsional axis and further comprising

a fifth member in the form of a ring having an inner concave spherical periphery centred about the further central point and complementary to the outer periphery of the fourth member and arranged to co-act with the fourth member to transmit load therebetween, and

a further axle arrangement perpendicular to the said another axle arrangement and coupling the fourth and fifth members independently of the first, second and third members.

22. A coupling or coupling arrangement according to any preceding claim, wherein the or each axle arrangement is configured to not transmit radial loads between the members coupled thereby.

23. A coupling substantially as hereinbefore described with reference to any one of Figures 2, 5 and 7, optionally as modified by one or more of Figures 8, 9, 10, 11 and 12 of the accompanying drawings.

24. A coupling arrangement substantially as hereinbefore described with reference to Figure 6A or 6B of the accompanying drawings.

Amendments to the claims have been filed as follows

CLAIMS

1. A coupling comprising:

a first annular member and a second annular member; the first annular member and the second annular member having a common centre on a torsional axis;

the first annular member having an outer convex spherical periphery;

the second annular member having an inner spherical concave periphery in which the outer convex periphery of the first annular member is received,

the outer convex periphery and the inner concave peripheries being concentric with the first annular and second annular and complementary to one another and co-acting with one another to transmit axial loads acting along the torsional axis between them; at least one axle disposed radially of the common centre of the first annular member and of the second annular member mounted within the first and second annular members coupling the first and second members for transmitting torsional load from one of the members to the other,

the first and second annular members being constrained by the axle(s) to be rotatable one relative to the other about the axle(s).

2. A coupling according to claim 1, wherein the first annular member has splines around its inner periphery for engaging a correspondingly splined shaft.

3. A coupling according to claim 1 or 2, wherein the convex and concave spherical surfaces are co-acting bearing surfaces of the coupling are contiguous plain bearing surfaces which bear radial loads of the coupling and which bear loads of the coupling acting along the said torsional axis.

4. A coupling according to any one of claims 1 to 3, further comprising a ball or roller bearing arrangement between the convex and concave spherical surfaces.

5. A coupling according to claim 4, wherein the bearing arrangement between the convex and concave spherical surfaces comprises balls within a cage.

6. A coupling according to any preceding claim, wherein the second annular member is configured to retain the first member within the coupling.

7. A coupling according to any preceding claim, wherein one of the inner member and the outer ring is fixed against rotation about the torsional axis.

8. A coupling according to any preceding claim, wherein the second member has an outer periphery which is convexly spherical and further comprising a third annular member concentric with the first and second annular members having an inner concave spherical periphery, the outer convex periphery of the second annular member and the inner concave periphery of the third annular member are concentric with the first, second, and third members, and complementary to one another and arranged to co-act with the second annular member to transmit load between them,

the second annular member and third annular member being coupled by at least one second axle(s) perpendicular to the first axle(s),

the second member and third annular members being further rotatable one relative to the other about the centre of the second and third annular members constrained by the second axle(s) independently of the first and second members.

9. A coupling according to claim 8, wherein the third member has an outer periphery which is convexly spherical about a further centre which is offset

from the centre of the first, second and third annular members in the direction of the torsional axis and further comprising a fourth annular member having an inner concave spherical periphery centered about the further centre and complementary to the outer periphery of the third annular member and arranged to co-act with the third member to transmit load between them, and a third pair of diametrically opposed axles perpendicular to the first pair of diametrically opposed axles coupling the third and fourth members independently of the first, second and third annular members, the third member and fourth annular members being further rotatable one relative to the other about the said further centre in a direction constrained by the third pair of diametrically axles arrangement independently of the first, second and third annular members; and wherein the fourth annular member has an outer periphery which is convexly spherical about the further centre which is offset from the centre of the first and second annular members in the direction of the torsional axis and further comprising a fifth annular me having an inner concave spherical periphery centered on the further centre and complementary to the outer periphery of the fourth annular member and arranged to co-act with the fourth member to transmit load between them, and a fourth pair of diametrically opposed axles, the fourth pair of diametrically opposed axles perpendicular to the third pair of diametrically opposed axles coupling the fourth and fifth annular members independently of the first, second and third annular members.

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10. A coupling according to any preceding claim in which the at least one axle(s) comprise pairs of diametrically opposed axles.

11. A coupling arrangement comprising two couplings according to any preceding claim connected by a connecting structure.

12. A coupling arrangement according to claim 11, wherein the connecting structure couples the outermost annular member of the couplings.

13. A coupling arrangement according to claim 11, wherein one of the couplings is free to move relative to the connecting structure.

14. A coupling according to claim 13, wherein the connecting structure connects the outermost annular member of one of the couplings to the first annular member of the other.

15. A coupling or coupling arrangement according to any preceding claim, wherein the axles are configured to not transmit radial loads between the members coupled thereby.

16. A coupling according to any preceding claim, wherein the outermost annular member has means for coupling to a structural element.

17. A coupling according to claim 16, wherein the coupling means comprises splines.

18. A coupling according to any one of the preceding claims in which one member other than an outer most member is retained axially by a second member outside the one member over the operational range of rotation of the members with respect to one another.

19. A coupling according to claim 18 in which each said second member(s) has a pair of diametrically opposed loading slot by which the said one member may be inserted to be retained with the said second member.

20. A coupling substantially as hereinbefore described with reference to any one of Figures 2, 5 and 7, optionally as modified by one or more of Figures 8, 9, 10, 11 and 12 of the accompanying drawings.

21. A coupling arrangement substantially as hereinbefore described with reference to Figure 6A or 6B of the accompanying drawings.

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Claims searched:	1-24	**Date of search:**	24 June 2014

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-8, 11-14, 17 & 22	WO 94/29604 A (CORNAY, P. J.) especially see the figures
X	1-8, 11-14 & 22	JP S5821023 A (TOKAI TRW & CO) especially see figures 1 & 3 and the abstract

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X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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F16D

The following online and other databases have been used in the preparation of this search report

Online: WPI & EPODOC

International Classification:

Subclass	Subgroup	Valid From
F16D	0003/16	01/01/2006