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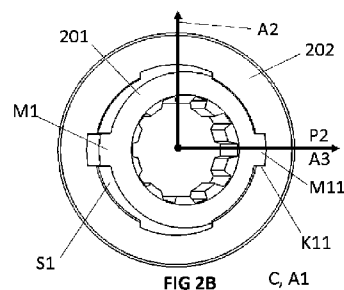
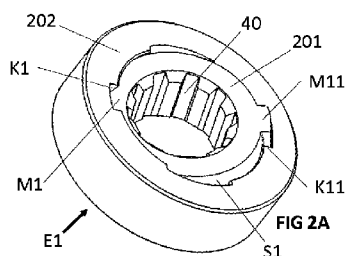
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(54) **Title:** COUPLING



(57) **Abstract:** A coupling comprises an inner member (1) having an outer convex spherical periphery (S1) centred about a central point (C). The first inner member has a torsional axis (A1) extending through the central point. A second member outer ring (2) has an inner concave spherical periphery centred on the central point and complementary to the outer periphery of the inner member. One of the first inner member (1) and second member (2) has an elongate projection (M1) projecting parallel to a line extending radially of the central point into a corresponding elongate slot (K1) in the other. The slot and projection are elongate in a plane parallel the torsional axis (A1). The projection and slot act to transmit torque about the torsional axis (A1) from one to the other. The inner member and second member are rotatable one relative to the other about the said central point in a direction constrained by the projection and slot.

Description

Title of Invention: COUPLING

Technical Field and Background

[0001] This invention relates to a coupling.

[0002] 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 of the invention

[0003] According to the present invention a coupling having an inner member and an outer annular member comprises one or more pairs of members, which may or may not include one or both the innermost and outermost members, each pair being a first member and a second annular member with a common axis and having a common first centre on the axis;

- the first member having an outer convex spherical periphery;
- the second annular member having an inner spherical concave periphery into which the outer convex periphery of the first annular member is received;
- the outer convex periphery and the inner concave peripheries being concentric about the first centre 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 elongate projection from one member of a pair of members into an elongate slot in the other of the pair of members, each projection and each slot being elongate in a plane containing or parallel to the central axis of the pair of members concerned, the slot and projection projecting in the direction of the said plane, and arranged to co-act with the pair of members to transmit torque from the innermost of the pair of members to the other member of the pair;
- each member, other than the inner member, having a pair of diametrically opposed loading slots extending half way across their width to enable the introduction of the first member of a pair of members into the concave inner periphery of the second of the pair of members, and to be retained axially by the second of the pair of members.

[0004] For most practical applications the said members, other than the outer member, comprise spherical segments including a common centre.

[0005] A spherical segment is a portion of a sphere between with a pair of parallel planes.

However, it is possible to consider, in some circumstances, situations in which a segment of a sphere is used in which the planes are not parallel but non-intersecting or which is cut by cones whose apexes are on the common axis - such alternatives would have disadvantages both in manufacture, assembly and use and seem less likely to be adopted.

[0006] Other features of the invention are found in the claims and/or the accompanying description.

[0007] Couplings according to the invention may be used for coupling any two structural elements that must be coupled with at least one rotational degree 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, various couplings according to the invention may be used to couple angularly misaligned shafts, such as universal joints, constant velocity joints, couplings for coupling a drive shaft to a driven shaft, or as couplings for connecting a torque shaft to a fixed structural element, as in, for example, a suspension system.

Brief Description of Drawings

[0008] Examples of the invention described below with reference to the accompanying drawings, in which:

[0009] Figure 1 illustrates a reference frame of operation of couplings according to embodiments of the invention;

[0010] Figures 2A to 2D show an example of a coupling according to the invention, of which Figure 2A is an isometric view of a coupling with its elements un-aligned, Figure 2B is an axial side view of a coupling in the frame of reference, Figure 2C is a cross-sectional view along axis A2 of Figure 2B and Figure 2D is a cross-sectional view along the axis A3 of Figure 2B;

[0011] Figures 3A to 3E illustrate a method of assembling the coupling of Figure 2;

[0012] Figures 4A and 4B show a hub centre steering mechanism including an example of a coupling in accordance with the invention;

[0013] Figures 5A and 5B are cross-sectional views of pairs of couplings connected together;

[0014] Figures 6A to 6C show another example of a coupling according to the invention, of which Figure 6A is a cross-sectional view of Figure 6B along axis A2, Figure 6B is an axial view along axis A1 of Figure 1, and Figure 6C is a perspective view in which the elements of the coupling are misaligned;

[0015] Figures 7A to C show a pair of the couplings connected together, in which Figure 7A is a cross-sectional view with the elements of the couplings aligned, Figure 7B shows

the elements un-aligned, and Figure 7C is an isometric view in which the elements are unaligned;

- [0016] Figure 8A to 8E show a further example of a coupling according to the invention, of which Figure 8A is an axial view along axis A1 of Figure 1, Figure 8B is an isometric axial view showing the elements of the coupling un-aligned, Figure 8C is a cross-sectional view along axis A3, Figure 8D is a cross-sectional view along axis A2 and Figure 8E is a side view of the coupling as shown in Figure 8A;
- [0017] Figures 9A to 9E show bearings in examples of couplings according to the invention, in which Figure 9A is an axial view of an element of a coupling, Figure 9B is a side view of the element of Figure 9A, Figure 9C is a top view of the element of Figure 9A, Figure 9D is a cross sectional view of a coupling and Figure 9E is an isometric view of a coupling;
- [0018] Figure 10 shows means for limiting relative rotation of elements of a coupling according to the invention;
- [0019] Figure 11 is a schematic diagram of a projection and slot useful in examples of couplings according to the invention;
- [0020] Figure 12A is a cross-sectional view of a modification of the couplings of the preceding drawings showing the elements un-aligned and Figure 12B is an isometric view of the coupling of Figure 12A;
- [0021] Figures 13A to 13C show a yet further example coupling according to the invention, of which, Figure 13A is an axial view along axis A1 of Figure 1, Figure 13B is a perspective view showing elements of the coupling un-aligned, and Figure 13C is another isometric view showing elements of the coupling un-aligned;
- [0022] Figures 14A to 14E show yet another example of a coupling according to the invention, of which Figure 14A is a axial view along axis A1 of Figure 1 with elements of the coupling un-aligned, Figure 14B is an axial cross-sectional view along plane C-C of Figure 14D, Figure 14C is a cross-sectional view along plane A-A in Figure 14A, Figure 14D is a side view of the coupling of Figure 14A, and Figure 14E is an isometric view of the coupling;
- [0023] Figures 15A and 15B show another example of a coupling according to the invention;
- [0024] Figure 16 shows an example of a coupling combining the use of projections and slots in part of the coupling and axles in another part, wherein Figures 16A, 16B, 16D are rear, front and side isometric views of the coupling with the members unaligned; and Figure 16C is a cross sectional view of the coupling, and
- [0025] Figures 17A to 17D shows another example of a coupling according to the invention, in which Figure 17A is an isometric front view of the coupling, Figure 17B is an isometric rear view of the coupling, Figure 17C is a cross-sectional view on axis A3

and Figure 17D is an isometric side view.

Descriptions of examples

- [0026] Examples of the invention in figures 2 to 17 are described in relation to a reference frame as shown in Figure 1.
- [0027] The reference frame has a first axis A1 defining an axial direction. A second axis A2 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. A third plane P3 through the central point C is perpendicular to the other planes. A third axis A3, perpendicular to axes A1 and A2, lies in the third plane and passes through the central point C.
- [0028] The first axis A1 is a torsional axis on which for example, 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.
- [0029] In some examples, couplings have some members centred on the central point C and other members centred on a further central point C2 offset from C along the first axis A1 when the members are aligned. The offset of C2 from C may be slight, for example a fraction of a millimetre. Further axes A21 and A31, parallel to axes A2 and A3 respectively pass through the central point C2.
- [0030] In Figure 2, a coupling comprises a pair of members, 201 and 202, an inner annular member 201 and an outer annular member 202 each comprising spherical segments. The inner annular member 201, around axis A1, is centred on the central point C which is on that axis and has an outer peripheral surface S1 which is convexly spherical and centred on the central point C. The inner annular member 201 has a central aperture 40 which in this example has splines 42 for engaging a correspondingly splined shaft.
- [0031] An outer annular member 202 has an inner peripheral concave spherical surface S21 which is complementary to the convex outer surface S1 of the inner member 201. The concave spherical surface S21 is centred on the same central point C. The inner spherical surface S21 of the outer member 202 and the outer spherical surface S1 of the inner member 201 are contiguous plain bearing surfaces.
- [0032] Elongate projections M1 and M11 extend radially of the central point C, and parallel to the first axis A1, from the convex spherical surface S1 of the inner member 201. The outer surfaces of the projections also extend parallel to the spherical surface S1. The projections extend into complementary slots K1 and K11 in the inner concave surface S21 of the outer annular member 202. The projections and slots constrain the inner and outer annular members 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. Projection M11 and slot K11 are identical to, and diametrically opposite, projection M1 and slot K1 respectively. The coupling will work without projection M11 and slot K11, but it is less robust against failure.

- [0033] The central point C of the adjacent convex and concave spherical surfaces S1, S21, lies between the axial facing faces F1 and F3 of the inner member 201 and between the outer faces F2 and F4 of the outer member 202. 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 202 at the axially facing faces thereof F2 and F4. Thus the inner annular member is retained axially in the outer annular member over the operational range of rotation of the outer member 202 about the second axis.
- [0034] In the examples E1 shown in Figures 2 there are splines 42 in the central bore of inner member 201 for engaging a shaft. Splines (not shown) may additionally or alternatively be provided on the outer periphery of the outer member 202 for engaging another shaft. The coupling may be allowed to slide relative to the shaft(s) providing an axial degree of freedom.
- [0035] In the example shown the projections M1, M11 which fit into associated slots K1, K11 with minimal clearance between the sides of the projections and the sides of the slots. However in another example one of the projections projects into its associated slot with a predetermined substantial clearance between the sides of the projection and the sides of the slot to act as a back-up if the other projection, which fits into its associated slot with minimal clearance, fails.
- [0036] The inner 201 and outer 202 members are both annular in 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.
- [0037] As shown in Figure 2A to 2D, the projection(s) project(s) from the inner annular member 201 into slot(s) in the outer member 202. However the projection(s) may project from the outer member into slot(s) in the inner annular member 201.
- [0038] In figure 2, the spherical surfaces bear loads acting radially of the axis and in the direction of the axis. The projection and slot transmit torque about the first axis between the inner and outer members. The inner member 201 and outer member 202 comprise spherical segments.
- [0039] In one use of the coupling, rotation of the shaft about the first axis is transmitted from the inner member 201 by the projections M1 and M11 and slots K1 and K11 to the outer member 202 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.

- [0040] Figures 3A to 3E illustrate how the coupling in figure 2 is assembled. The same method is used of all the other couplings illustrated in figures 4 to 17 below. The outer member 202 has two, diametrically opposite loading slots L1 and L2. As shown in Figure 3E, the slots extend halfway across the width of the outer member. The slots are dimensioned so that the diametrically opposite floors 6 of the slots are spaced by the diameter of the outer surface S1 of the inner member 201. The width of each slot is equal to or slightly greater than the width of the inner member. The inner member 201 is introduced sideways into the slots as shown in Figures 3A, 3B and 3C with its projection(s) M1, M11 aligned with the slot(s) K1, K11 and then rotated so the projection(s) enter(s) the slot(s).
- [0041] Other couplings described below have two or more annular members around the inner member concentric rings. Each pair of annular members may be assembled as described with reference to figure 3. It will be noted that Figures 3D and 3E show an annular member 602 of, for example, the embodiment of Figure 6A to 6C which has two annular members around the inner member, intermediate annular member 602 fitting within the outermost annular member 603.
- [0042] The assembly method of Figure 3 provides a robust, strong, coupling. It enables the individual members to be machined from solid material and minimises the risk of failure as a result of joining two halves of members together. The method described enables all the bearing surfaces described in this specification to be continuous i.e. avoiding any joins (and thus weak areas) at the join of a member assembled in two halves bolted or welded together.
- [0043] One possible use of the coupling of Figure 2 is in a hub centre steering mechanism of a vehicle. In Figure 4 a steered wheel hub 62 is supported by a support member 64 which in this example is a suspension arm.
- [0044] The coupling P1 couples the suspension arm 64 to the steered wheel hub 62. The arm 64 is engaged by splines 42, in the central aperture 40 of the first inner annular member 201 of the coupling. The projection(s) M1, M11 and slot(s) K1, K11 allow the outer member 202 to rotate about one axis (the steering axis) relative to the first inner annular member 201 and arm 64. The outer member 202 supports the wheel 62 which is free to rotate on bearings 63. A steering arm 60 is fixed to the outer annular member 202 to rotate it relative to the first inner annular member and shaft 64.
- [0045] In this example the projection(s) M1, M11 and slot(s) K1, K11 provide support to allow relative rotation but do not drive the wheel hub 62.
- [0046] Figure 5A shows a coupling arrangement comprising two couplings as shown in Figure 2 connected together by a connecting structure 66. The structure 66 rigidly connects the two couplings. In Figure 5A it connects the outer member 202 of the couplings. The projections of the two couplings are orthogonal relative to each other,

but could be non-orthogonal. In the example of Figure 5A the connecting structure is a tube coupling the outer members. In a modification of Figure 6A, one of the couplings is fixed in the tube and the other is free to move axially within the tube.

[0047] In another example, shown in Figure 5B, the outer member 202 of one coupling is connected to the inner member 201 of the other by a connecting structure shown schematically at 68.

[0048] One illustrative use of such a coupling is a crank handle. If the projections of the two couplings are in the same orientation. In other examples the projection(s) of one coupling are orthogonal to the projection(s) of the other.

[0049] In Figures 6A to 6C, a coupling comprises a first, inner annular member 601, annular intermediate member 602 and an annular outermost member 603. Each of the members 601, 602, 603 comprises spherical segments about the centre C. The inner annular member 601 is centred on a first axis A1, the inner annular member 601 having an outer peripheral surface S1 which is convexly spherical centred on the point C on the axis A1. The first inner annular member 601 has a central bore 40 which in this example has splines 42 for engaging a correspondingly splined shaft.

[0050] The intermediate annular member 602 has an inner peripheral surface S21 which is concavely spherical complementary to the outer surface S1 of the first inner member 601. In this example the inner spherical surface S21 of the intermediate member 602 and the outer spherical surface S1 of the first inner member 601 are contiguous plain bearing surfaces.

[0051] Diametrically opposite elongate projections M1 and M11 extends radially of, and parallel to, the first axis A1 from the convex spherical surface S1 of the inner member 601. The radially outer surface of the projection also extends parallel to the spherical surface S1. The projections extend into complementary slots K1 and K11 in the inner concave surface S21 of the intermediate member 602. The projections M1, M11 and slots K1 K11 constrain the first inner 601 and intermediate member 602 members to be rotatable one relative to the other about the second axis A2 of rotation through and perpendicular to the first axis A1.

[0052] The intermediate member 602 has an outer periphery S22 which is convexly spherical. The outermost annular member 603 has an inner peripheral surface S31 which is concavely spherical complementary to the outer surface S22 of the intermediate member 602. In this example the inner spherical surface S31 of the outermost member and the outer spherical surface S22 of the intermediate member 602 are contiguous plain bearing surfaces.

[0053] Second elongate projections M2 and M22 extend radially of, and parallel to, the first axis from the convex spherical surface S22 of the intermediate member 602. The radially outer surface of the second projections M2 and M22 also extends parallel to the

spherical surface.

- [0054] The projections M2 and M21 extend into complementary, second, slots K2 and K21 in the inner concave surface of the outermost member 603. The second projection M2 and M21 and second slots K2 and K21 are perpendicular to the first projections M1, M11, and first slots K1, K11. They constrain the intermediate 602 and outermost 603 members to be rotatable one relative to the other about the third axis A3 of rotation (see Figure 1) through the centre point C, and perpendicular to both the first axis A1 and second axis A2.
- [0055] The inner member 601 is retained in the intermediate member 602, and the intermediate member 602 is retained in the outermost member 603.
- [0056] In this example the second projections M2 and M21 and corresponding slots K2 and K21 could be omitted but with less security in the event of failure.
- [0057] One use of the couplings of Figure 6 is as a universal joint as it allows angular misalignment of the shafts by virtue of the relative rotation of the inner and outermost members about the second axis.
- [0058] The coupling of Figure 6 has a flange 44, fixed to or integral with the third annular member for connecting the third annular member to a structural element, for example a shaft. The flange 44 may be replaced by splines or some other connecting means.
- [0059] The projections M1, M11 and M2 M21 may be in intermediate member 602 and outermost member 603 respectively projecting into slots K1, K11, K2, K21 in inner member 601 and intermediate member 602.
- [0060] The pairs of members 601 and 602, and 602 and 603 each comprise a pair of members within the meaning the claims below.
- [0061] Figure 7 shows a coupling arrangement comprising two couplings E2 of the kind shown in Figure 6 (without the flange 44) connected together by a connecting structure 66. The structure rigidly connects the two couplings. In Figure 7 it connects the outermost members 603 of the couplings. In the example of Figure 7 the connecting structure is a tube coupling the outer members. In another example, instead of the tube, the outermost member of one coupling is connected to the inner member of the other. One illustrative use of the coupling of Figure 7 is as an approximation to a double Cardan shaft arrangement, if the projection or projections of one of the couplings are non-orthogonal to those of the other. One of the couplings E2 may be free to move axially in the tube 66.
- [0062] The projections M1, M11, M2, and M21 of one coupling may be orthogonal to those of the other or preferably parallel to those of the other in further examples depending on the application.
- [0063] In Figures 8A to 8E the coupling comprises an inner, annular member 801 centred on the central point C on the first axis A1, first, second and third intermediate annular

members 802, 803, and 804, and outer annular member 805. The members 801 and 802 and their spherical bearing surfaces are concentric about central point C. The members 804 and 805 and their spherical bearing surfaces are concentric about a central point C2 offset along axis A1 as described in the reference frame of figure 1. The second intermediate member 803 has its inner spherical surface centred on C and its outer spherical surface centred on C2.

- [0064] The inner annular member 801 has an outer peripheral surface S1 which is convexly spherical centred on the central point C on the first axis A1. The inner annular member 801 has a central aperture which has splines for engaging a correspondingly splined shaft.
- [0065] A first intermediate member 802 has an inner peripheral surface S21 which is concavely spherical complementary to the outer surface S1 of the first annular member 801. In this example the inner spherical surface S21 of the annular member 802 and the outer spherical surface S1 of the first annular member 801 are contiguous plain bearing surfaces.
- [0066] Diametrically opposed elongate projections M1 and M11 extend radially of, and parallel to, the first axis A1 from the convex spherical surface S1 of the inner ring 801. The radially outer surface of the projections M1 and M11 also extends parallel to the spherical surface S1. The projections extend into complementary first slots K1 and K11 in the inner concave surface S21 of the first intermediate annular member 802. The first projections and first slots constrain the pair of members comprising the inner member 801 and first intermediate annular member 802 to be rotatable one relative to the other about second axis A2 perpendicular to the first axis A1.
- [0067] The first intermediate annular member 802 has an outer periphery S22 which is convexly spherical. A second intermediate annular member 803 has an inner peripheral surface S31 which is concavely spherical complementary to the outer surface S22 of the first intermediate annular member 802. In this example the inner spherical surface S31 of the second intermediate member 803 and the outer spherical surface S22 of the first intermediate annular member 802 are contiguous, plain, bearing surfaces.
- [0068] Second elongate projections M2 and M21 extends radially of, and parallel to, the first axis A1 from the convex spherical surface S22 of the first intermediate member 802. The radially outer surface of the second projections M2 and M21 also extend parallel to the spherical surface S22. The projections extend into a complementary, second, slots K2 and K21 in the inner concave surface S31 of the second intermediate member 803. The second projections M2 and M21 and second slots K2 and K21 are perpendicular to the first projections M1, M11 and first slots K1 and K11. They constrain the pair of members comprising the first intermediate annular member 802 and the second intermediate annular member 803 to be rotatable one relative to the other about

third axis A3 through the central point C, and perpendicular to the first and axes A1 and A2.

- [0069] The second intermediate annular member 803 has an outer periphery S32 which is convexly spherical. A third intermediate annular member 804 has an inner peripheral surface S41 which is concavely spherical complementary to the outer surface S32 of the second intermediate annular member 803. In this example the inner spherical surface S41 of the third intermediate annular member 804 and the outer spherical surface S32 of the second intermediate annular member 803 are contiguous, plain, bearing surfaces.
- [0070] Third elongate projections M3 and M31 extends radially of, and parallel to, the first axis A1 from the convex spherical surface S32 of the second intermediate annular member 803. The radially outer surface of the projections M3 and M31 also extends parallel to the spherical surface S32. The projections M3 and M31 extends into a complementary, third, slots K3 and K31 in the inner concave surface of the third intermediate annular member 804. The third projections M3 and M31 and third slots K3 and K31 are in the same plane as projections M2 and M21, and slots K2 and K21 of and thus constrain the pair of members comprising the second intermediate member 803 and third intermediate member 804 to be rotatable one relative to the other about axis A3 parallel to axis A3. It will be seen that the second intermediate annular member 803 differs from the other annular members in that its internal slots K2 and K21 co-operating with projections M2 and M21 of the first intermediate annular member 802 is in the same plane as its projections M3 and M31.
- [0071] The third intermediate annular member 804 has an outer periphery S42 which is convexly spherical. A concavely spherical complementary to the outer surface S42 of the third annular member 804. In this example the inner spherical surface S51 of an outermost annular member 805 and the outer spherical surface S42 of the third intermediate annular 804 are contiguous, plain, bearing surfaces. Fourth elongate projections M4 and M41 extend radially of, and parallel to, the first axis A1 from the convex spherical surface S42 of the third annular member 804.
- [0072] The radially outer surface of the fourth projections M4 and M41 also extend parallel to the spherical surface. The projections extend into a complementary, fourth, slots K4 and K41 in the inner concave surface S51 of the outermost member 805. The fourth projections M4 and M41 and fourth slots K4 and K41 are perpendicular to the third projections M3, M31, and third slots K3, K31. They constrain the pair of members comprising the third intermediate annular member 804 and the outermost member 805 to be rotatable one relative to the other about axis A21 parallel to axis A2 as shown in Figure 8D. The further axis A21 is through and perpendicular to the first axis because the fourth projection M4, M41 and fourth slots K4, K41 are parallel to the first pro-

jections M1, M11 and first slots K1 and K11.

[0073] The members are assembled and retained in the coupling in the same way as described with reference to Figure 3.

[0074] As in previous examples projections M11, M21, M31 and M41 and corresponding slots K11, K21, K31 and K41 could be omitted but with less security in the event of failure.

[0075] In the examples of figure 8, it has been found that the third intermediate member and outermost members should be offset relative to the first and second members along the axis A1. This may be achieved by offsetting the outer spherical surface S32 of the second intermediate member 803 axially of the inner spherical surface S31 of the second intermediate member 803 as shown in Figure 8D.

[0076] One illustrative use of the coupling of Figure 8 is as an approximation to a constant velocity joint or double Cardan joint. In one double Cardan design the inner annular member 801 would be configured to move in the horizontal plane, the first intermediate annular member 802 would be configured to move in the vertical plane, the second intermediate annular member 803 would be configured to move in the vertical plane (but has the offset) and the third intermediate 804 would be configured to move in the horizontal plane. In another design, the inner annular member 801 is configured to move in a vertical plane, the first intermediate member 802 in a horizontal plane and so-on.

[0077] The projections may be in outer annular members projecting into slots in inner annular members in the examples of Figure 8.

[0078] The pairs of members 801 and 802, 802 and 803, 803 and 804, and 804 and 805 each comprise a pair of members within the meaning of the claims below.

[0079] Members 801 and 802 comprise spherical segments about the centre C. Members 803, 804 and 805 comprise spherical segments about the centre C2. However, the central aperture of second intermediate member 803 is a spherical segment centred on centre C.

[0080] In the examples of Figures 2 to 8, the spherical surfaces are all contiguous, plain, bearing surfaces. Ball barrel roller or other rotational bearings may be provided between the adjacent spherical surfaces of a pair of annular members.

[0081] Rolling element bearings may be provided on the projections.

[0082] Referring to Figures 9A, B and C rolling element bearings in the form of ball bearings 90 held in two cages 91 are provided between the inner member 901 of the pair of members 901 and 902. As an alternative or in addition roller bearings 92, held in cages G, are provided in recesses L2 in the sides of the projections M1 and M2.

[0083] Turning to figure 10, as discussed the spherical surfaces of pairs 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 means may be provided to limit the relative rotation of pairs of adjacent members. Such limiting means also assists the retention of each inner annular member in its associated outer annular member. In Figure 10 the limiting means may comprise a fixed pin N projecting from an outer member 1002 of a pair of members, 1001 and 1002 into a groove L in an adjacent member, in this example in a projection M1 of the inner annular member 1 of the pair of members. Other examples of such limiting means include a stop within the coupling and a support structure which limits movement.

[0084] Figure 11 shows the forms of projections, M1, M2... etc. A projection M projects into a slot K. As shown schematically in Figure 11, preferably the radially outer surface of the projection is spaced from the radial outer end of the slot to avoid or at least reduce radial loading on the projection.

[0085] The projections and slots of any of the examples of the invention may have an involute or pseudo-involute shape. The radially outer end of the projection M may be spaced from the radially outer face of the slot K to reduce radial loading on the projection and slot.

[0086] The purpose of the involute shape is to improve/reduce bearing pressure distribution on and stress distribution in the projection, as with involute splines.

[0087] In figure 11, the ends of the outer ends of the projections M1, M2 ... etc are shown as being of a part cylindrical profile in cross section, they can have a flat profile in cross section. Normally, lengthways, they are contoured to be concentric with the annular member with which they are associated. However, if the projections and associated slots are sufficiently deep and sufficient clearance allowed between the outer ends of the projections and the bases of the slots, the surfaces can be spherical, cylindrical or flat (straight through).

[0088] As shown in Figure 12, to increase the operational range of relative rotation, the outer one 2, or 3 of two adjacent pairs of members 1 and 2 or 2 and 3 may be larger in the axial direction A1 than the inner one 1 or 2. Figure 12 shows three annular members 1, 2 and 3. The principle of Figure 12 may be applied to any of the pairs of annular members of the examples of the invention. In other words the angle subtended at the centre by the inner spherical concave periphery of the outer member 2 or 3 is greater than the angle subtended at the centre by the outer spherical convex periphery of the inner member 1 or 2 as appropriate.

[0089] In all of the examples described above with reference to Figures 1 to 12, each projection M and associated slot K defines a radial plane P2 and or P3 coincident with the first axis A1 in which the adjacent members coupled thereby are constrained to rotate one relative to the other about an axis A2, A3, A21, or A31. It will be noted that in the examples described above the projections and slots all project radially of the

central point C or C2 on the axis A1.

[0090] As shown in Figure 13, each single projection and associated slot in adjacent pairs of members (shown in figure 13 as 1 and 2) of the examples described above may be replaced by two (or more) parallel, spaced apart, projections and slots. In the example shown in Figure 13 each single projection and slot is replaced by two projections M16, M16' and slots K16, K16', one projection and slot being each side of, and equidistant from, the said radial plane P of relative rotation. In the example of Figure 13 the projections and slots are each side of and equidistant from the plane P2.

[0091] In other examples each radially extending single projection and associated slot of the examples describe above may be replaced by a single projection and slot in a plane offset from and parallel to radial plane through the radially extending projection and slot.

[0092] Figure 14 shows an important embodiment of the invention for use in highly safety critical applications, such as found in the aircraft industry. In figure 14 axles X are be provided in addition to the projections M and slots K for coupling adjacent members. Figure 14 shows a modification of the coupling of Figure 6 in which axles X2, X21, and X1, X11 are provided on the axes A2 and A3 respectively, defined by the projections M1, M11, M2, M21 and slots K1, K11, K2, K21, of relative rotation of the adjacent pairs of members 601 and 602 and 602 and 603. The axles joining adjacent members may comprise two diametrically opposed shafts fixed at one end to the outer of the two members and projecting into a bore in the outer surface of the inner one of the two members. Each such shaft acts as a plain bearing in the inner one of the two members. A ball roller or other rotational bearing may be provided around the shaft in the inner one of a pair of members.

[0093] The axles X have clearance around their bores in the inner of the pair of annular members. For example in Figure 14B axles X2 and X21 have clearance within their bores in annular member 602, nor do their bases touch the projections M1 and M11. Similarly axles X1 and X11 have no contact with inner annular member 601 in figure 14C. As a result, normally torsional loads are transmitted between the members 601, 602, 603 through the projections and slots M1, M2...etc. K1, K2...etc. If a projection say M1 fails, projection M11 provides sufficient redundancy to enable normal operation. However if projection M11 also fails, then axles X1 and X11 can replace them in transmitting torsional loads. Even then there is further redundancy as the coupling can continue operation even if one of the axles X1 and X11 fails. This redundancy provides sufficient continuity of safe operation to enable the failures to be identified in normal maintenance, and the coupling replaced.

[0094] In the preceding paragraph, the coupling is designed so that torsional loads will normally be transmitted by the projections and slots. By designing narrow projections

(or wider slots), and reducing the clearance around the axles, the position can be reversed with the axles normally bearing the loads and the projections and slots acting as back –up in the event of failure.

- [0095] Axles may be provided in addition to the projections and slots on some but not all pairs of members in examples where there are a plurality of pairs of members as in figures 6 and 8. For example, the axles may only be provided in addition to the projections and slots on the inner most pair of members i.e. members 601 and 602 in figures 6 and 801 and 802 in figures 8.
- [0096] Figure 15 shows another modification of the coupling shown in Figure 6. In Figure 15, the inner member 601 has diametrically opposite radially projecting projections M1 and M11 projecting from the outer spherical surface into complementary slots K1 and K11 in the inner spherical surface of the intermediate member 602. The projections constrain the first and second members to be relatively rotatable in the plane of the projections.
- [0097] The intermediate member 602 has an outer spherical surface engaged with an inner concave surface of the outermost member 603. The second member and third member are coupled by axle shafts X23 and X23 coplanar (aligned with) with the projections M1, M11 so that the pair of members 602 and 603 are relatively rotatable orthogonally to the relative rotation of the pair of members 601 and 602.
- [0098] Such a coupling is useful because the torque between the intermediate and outer members 602 and 603 is relatively lower than the torque between the inner and first intermediate members 601 and 602.
- [0099] The projections M1 and M11 may be in intermediate member 602 projecting into slots in the inner member 601 in the example of Figure 15.
- [0100] Figure 16 shows a modification of the example of Figure 8 in which the projections between the pairs of members comprising the second and third intermediate members 803 and 804 and the third intermediate member 804 and outermost member 805 are replaced by axles X34, X341, X45 and X451. There may be one axle shaft or, as shown, two diametrically opposite axle shafts coupling adjacent pairs of members 803 and 804, and 804 and 805. The third member is thicker radially than the third member of Figure 8 because it must accommodate both slot(s) associated with projection(s) of the second member and axle shaft(s) connecting it to the fourth member. As shown in Figure 8 the second intermediate member 803 provides an axial offset between the inner group of the inner member 801, first intermediate member 802 and second intermediate member 803 and the outer group of the second intermediate member 803, third intermediate member 804, and outermost member 805.
- [0101] Such a coupling is useful because the torque at the outer group is relatively lower than the torque applied to the inner group.)

- [0102] Referring to Figure 17, any of the examples of a coupling shown in figures 2, 6, 8, 14, 15 and 16 may be fixed within a bearing 1701 which may be fixed by for example a flange 1702 to a fixed structure 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, 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.
- [0103] Figure 17 shows one coupling within a bearing. In the examples of figures 5 and 7 the two couplings joined in tandem by a tube 66, may be supported within a bearing around the tube 66.
- [0104] In further arrangement a shaft is fixed to, or integral with the innermost, member of a coupling. In another arrangement, a shaft is fixed to, or integral with, the outermost, member of a coupling. Shafts may be fixed to, or integral with, both the innermost and outermost members of a coupling.
- [0105] The examples described above may have splines in the inner member and or on the peripheral surface of the outermost member to connecting the coupling to structural elements to be coupled.
- [0106] 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 central aperture as shown in Figure 2, may have a screw thread or keys to couple to a shaft which is screw threaded or has keys slots. Especially for those examples having two or more projections on a member, the projections should share loads substantially equally. For plain bearing surfaces, the surfaces of the projections and slots should match accurately. Also for plain bearing surfaces, the mating convex and concave spherical surfaces should match accurately. That requires appropriately precise manufacture of the couplings.
- [0107] In one illustrative method of making the couplings a lining material is injected between the projections and slots to provide a precise fit. Likewise a lining material may be injected between the spherical bearing surfaces. The convex spherical surfaces may be accurately machined. The convex spherical surfaces may be roughly machined to form a rough surface which is also a piece-wise linear approximation to a curved surface, 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.
- [0108] Plastic could be injected to provide the bearing liner material; the compositions of some of the plastics used for a liner are not known as the suppliers are commercially

sensitive about their composition. However Delrin® is one known product that could be used or PTFE based materials could be used.

[0109] 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. and machined to shape or of plastic, e.g. nylon, glass filled nylon, acetal, ABS, Delrin® and moulded or machined to shape. In particular it can be seen that the use of loading slots as described with reference to figure 3 avoids the need to manufacture the annular members in two halves and bolt, weld or swage them together, which will always be a source of weakness, particularly in safety critical situations. It should be noted that the coupling of Figure 6 may be configured so that the inner 601 and the outermost member 603 are connected to shafts or other structural elements with only the intermediate member 602 free to move relative to the other two members; this might lead a designer to select brass or bronze for the moving intermediate member middle and steel for the inner member 601 and outermost member 603. The same philosophy could be applied to the other couplings. The choice of material depends on the intended use of the coupling.

[0110] The above embodiments are 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.

[0111] In the specific examples in figures 2 to 17, the inner member is an annular member with a central aperture to fit on a shaft. In some applications the inner member may have no central aperture, and can be bolted to a shaft or flange on the end of a shaft for example. Members other than the inner member have central apertures to allow a member within that member to nest.

[0112] In all the illustrated, the examples the members comprise spherical segments having parallel sides. It is feasible to construct couplings in which the sides are not parallel, however, in practice, such constructions are likely to be awkward to deploy.

[0113] The inner member in all the examples comprises an annular spherical member with a central aperture for receiving a shaft. However, it may not have a central aperture but, for example, be bolted to a flange on a shaft.

[0114] In the examples shown, for maximum compactness, in each member of a pair of members comprising spherical segments has parallel sides in common planes when the segments are aligned. In particular:

- in the arrangement of figure 2 each member of a pair of members comprises spherical segments has parallel sides in common planes when aligned;
- in the arrangement of figure 6 each member comprises spherical segments having parallel sides in common planes when aligned;
- in the arrangement of figure 8 the first pair of members (801, 802) each comprise spherical segments having parallel sides in common planes when aligned and the third pair of members (803, 804) and fourth pair of members (804, 805) each comprise spherical segments having parallel sides in common planes when aligned. This does not apply to the second pair of members (802, 803).

[0115] The discussion in the preceding paragraph, obviously, does not apply to a pairs of members in a coupling where the outer member of the pair has an enhanced operating range as shown in figure 12.

Claims

- [Claim 0001] A coupling having an inner member and an outer annular member comprising one or more pairs of members, which may or may not include one or both the innermost and outermost members, each pair being a first member and a second annular member with a common axis (A1) and having a common first centre (C) on the axis; the first member having an outer convex spherical periphery (S1); the second annular member having an inner spherical concave periphery (S21) into which the outer convex periphery of the first annular member is received; the outer convex periphery and the inner concave peripheries being concentric about the first centre (C) and complementary to one another and co-acting with one another to transmit axial loads acting along the torsional axis (A1) between them; at least one elongate projection (M) from one member of a pair of members into an elongate slot (K) in the other of the pair of members, each projection (M) and each slot (K) being elongate in a plane (P2) containing or parallel to the central axis of the pair of members concerned, the slot (M) and projection (K) projecting in the direction of the said plane (P2), and arranged to co-act with the pair of members to transmit torque from the innermost of the pair of members to the other member of the pair; each member, other than the inner member, having a pair of diametrically opposed loading slots extending half way across their width to enable the introduction of the first member of a pair of members into the concave inner periphery of the second of the pair of members, and to be retained axially by the second of the pair of members.
- [Claim 0002] A coupling according to claim1 in which the members, other than the outer member, comprise spherical segments including a common centre (C, C2).
- [Claim 0003] A coupling according to claim 1 or 2 comprising a pair of elongate projections (M) projecting radially of the central axis (A1) of one of the pairs of members into a corresponding elongate slots (K) in the other of the pair, the projections and slots being diametrically opposite one another and elongate in the said plane.
- [Claim 0004] A coupling according to any preceding claim, wherein the radially facing periphery of each projection (M) is spaced from the corresponding radially facing surface of the slot (K) into which it projects.
- [Claim 0005] A coupling according to any preceding claim, wherein the convex and

concave spherical surfaces (S1,S21...), which 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.

[Claim 0006] A coupling according to one of claims 1 to 4 further comprising a rolling element bearing (90, 92) between the convex (S21) and concave spherical surfaces (S1) and/or between the elongate facing side of each projection (M) and the corresponding elongate side of its associated slot (K).

[Claim 0007] A coupling according to any preceding claim having one intermediate annular member (602), the inner (601) and intermediate (602) members forming one pair of members and the intermediate (602) and outermost members (603) forming another pair of members, with at least one projection (M1, M2) from one of each of the pairs of members into at least one slot (K1, K2) in the other of each of the pairs of members and the plane containing the slot(s) and projection(s) between the intermediate (602) member and the outermost member (603) is orthogonal to the plane containing the slot(s) and projections between the inner member (601) and the intermediate member (602).

[Claim 0008] A coupling according to any one of claims 1 to 6 having first (802), second (803) and third (804) intermediate members, the inner (801) and first intermediate members (802) forming one pair of members, first (802) and second (803) intermediate members being a second pair of members, the second (803) and third intermediate (804) members being a third pair of members, and the third intermediate (804) and outermost (805) members being a fourth pair of members, with at least one projection (M) from one of each of the pairs of members into at least one slot (K) in the other of each of the pairs of members and the plane containing the slot(s) and projection(s) between one pair of members, except the third pair of members (803, 804), is orthogonal to that of the next lower ordinal pair of members preferably in which, in the case of the third pair, of members the plane containing the projections (M3, M31) and slots (K3, K31) is aligned with the plane containing the projections (M2, M21) and slots (K2, K21) of the second pair of members.

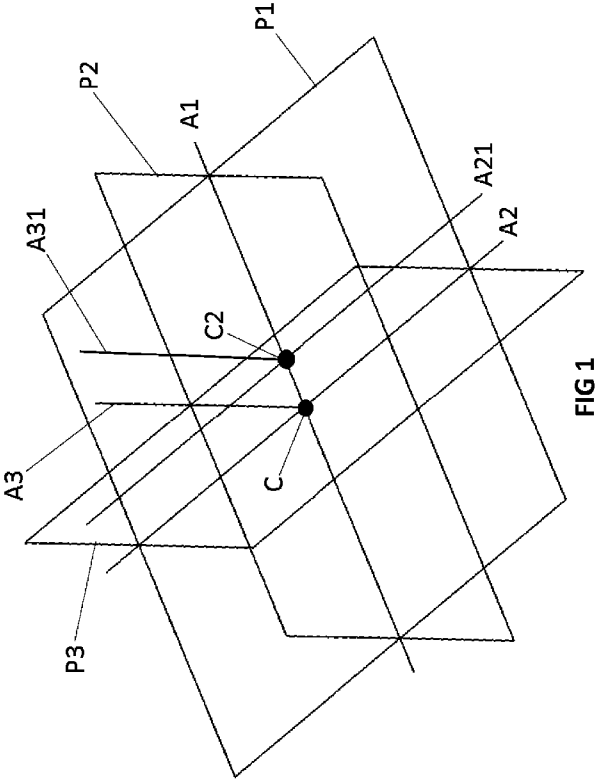
[Claim 0009] A coupling according to claim 8 in which the third intermediate (804) and outermost (805) members have a common second centre (C2) which is offset from the common first centre (C) along the central axis (A1) when the members are aligned with the second intermediate

member (803).

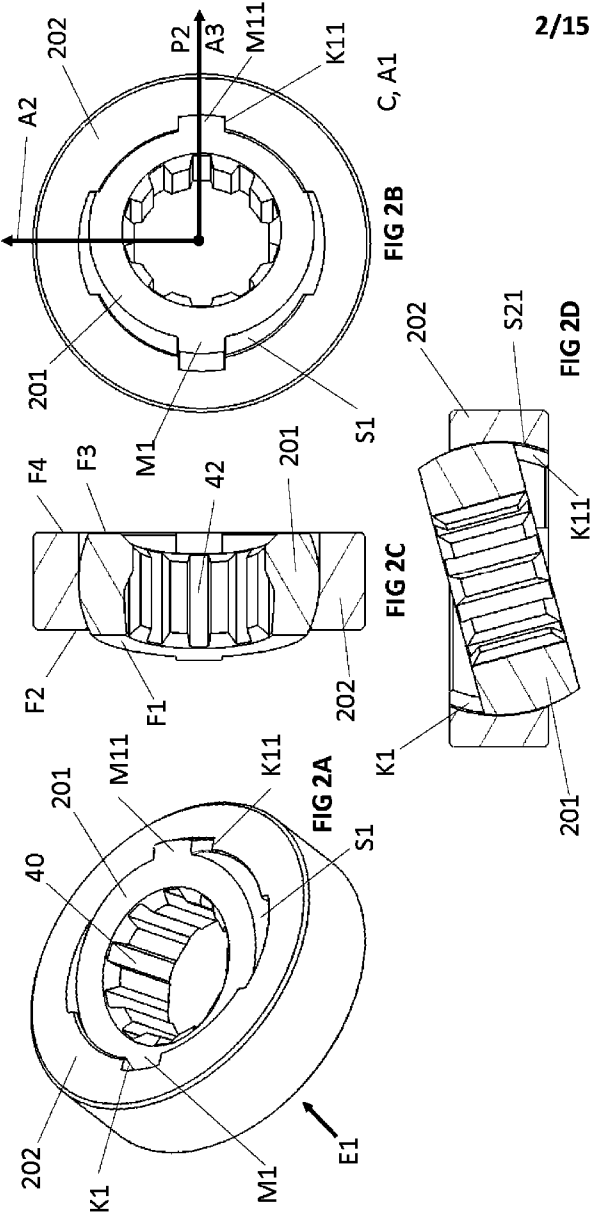
- [Claim 0010] A coupling according to claim 8 or 9 having its outer convex spherical periphery (S32) centred on the common second centre (C2) of the third intermediate and outermost members and its inner spherical concave periphery (S31) centred on the common first centre (C).
- [Claim 0011] A coupling according to any one of claims 7 to 10 having axles (X) instead of projections and slots between one or more pairs of members other than the first pair, the axis of each said axles being the axis of rotation of the outer of the pair of members about the inner of the pair of members.
- [Claim 0012] A coupling according to any of claims 1 to 10 further comprising at least one axle (X) coupling pairs of members, the axle being on the axis of rotation of one member relative to the other in a direction constrained by the projection and slot.
- [Claim 0013] A coupling according to any preceding claim wherein the angle subtended at the centre by the inner spherical concave periphery of the second member is greater than the angle subtended at the centre by the outer spherical convex of the first member.
- [Claim 0014] A coupling arrangement comprising two couplings (E1) each according to any preceding claim, wherein a connecting structure (66, 68) connects either both the outermost members (202, 603, 805, 902) of the couplings or the outermost member of one coupling (202, 603, 805, 902) to the innermost member (201, 601, 801, 901) of the other coupling by a connecting structure and in addition optionally provision is or is not be made for one of the couplings is free to move axially relative to the connecting structure.
- [Claim 0015] A coupling according to claim 1 comprising a further elongate projection (M16') projecting from one of a pair of members into a further slot (K16') in the other, the further projection (M16') and further slot (K16') projecting into and being elongate in a plane parallel and spaced from the first plane.

[Fig.]

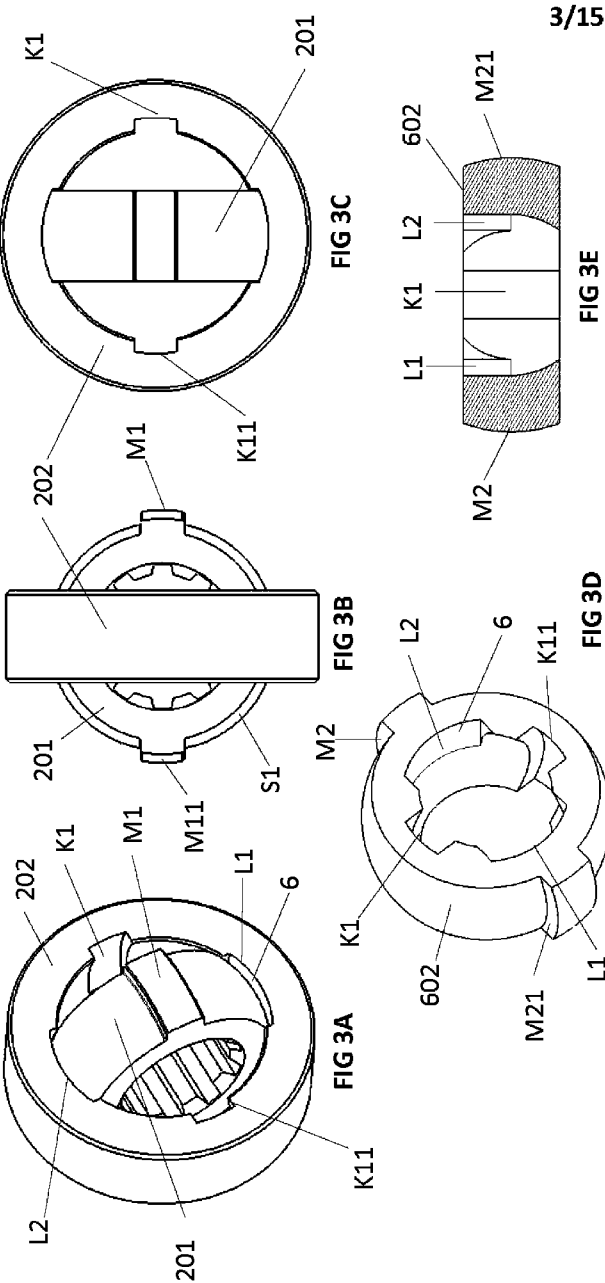
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[Fig.]

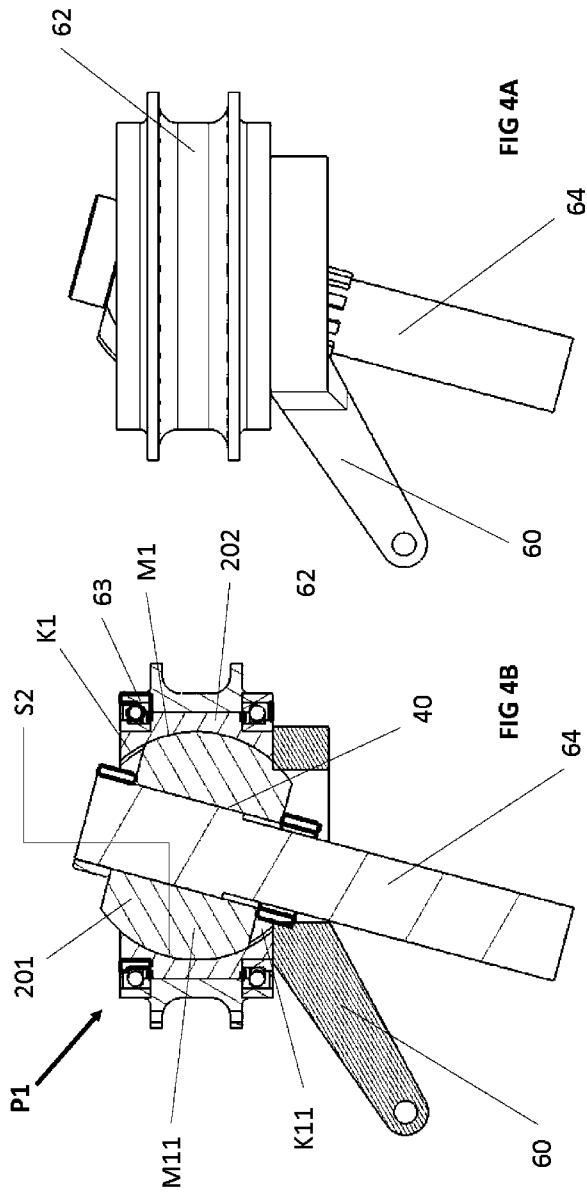


[Fig.]

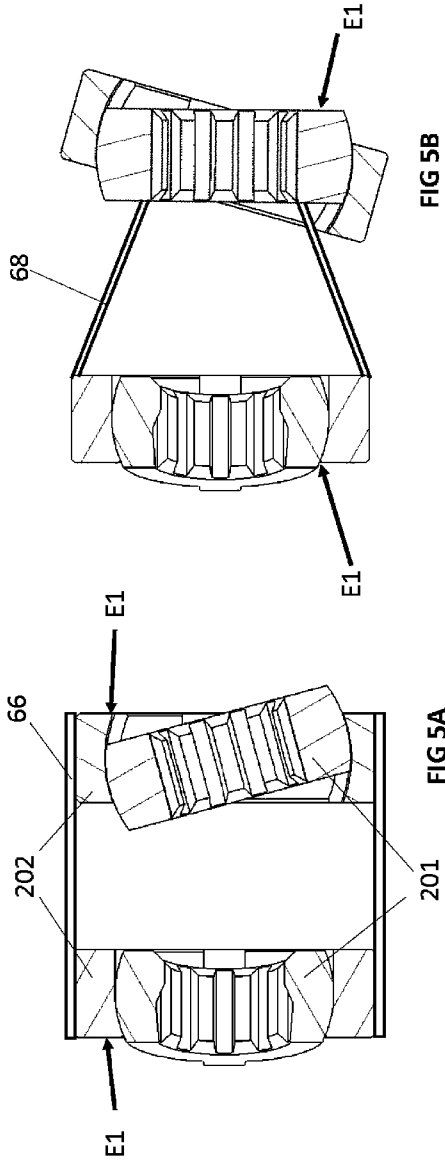


[Fig.]

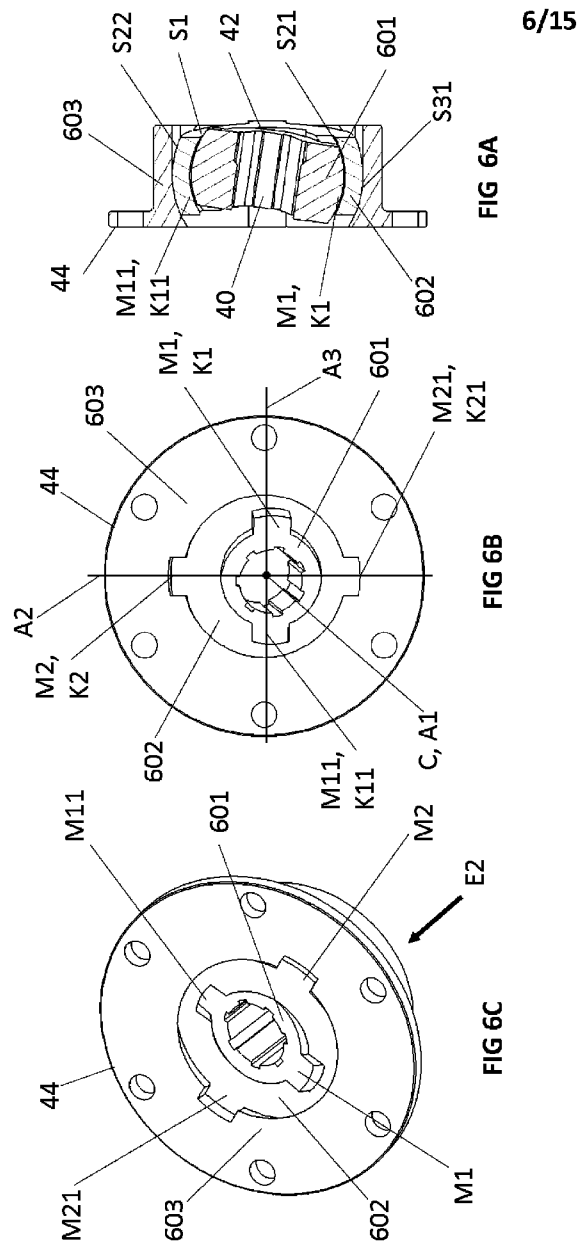
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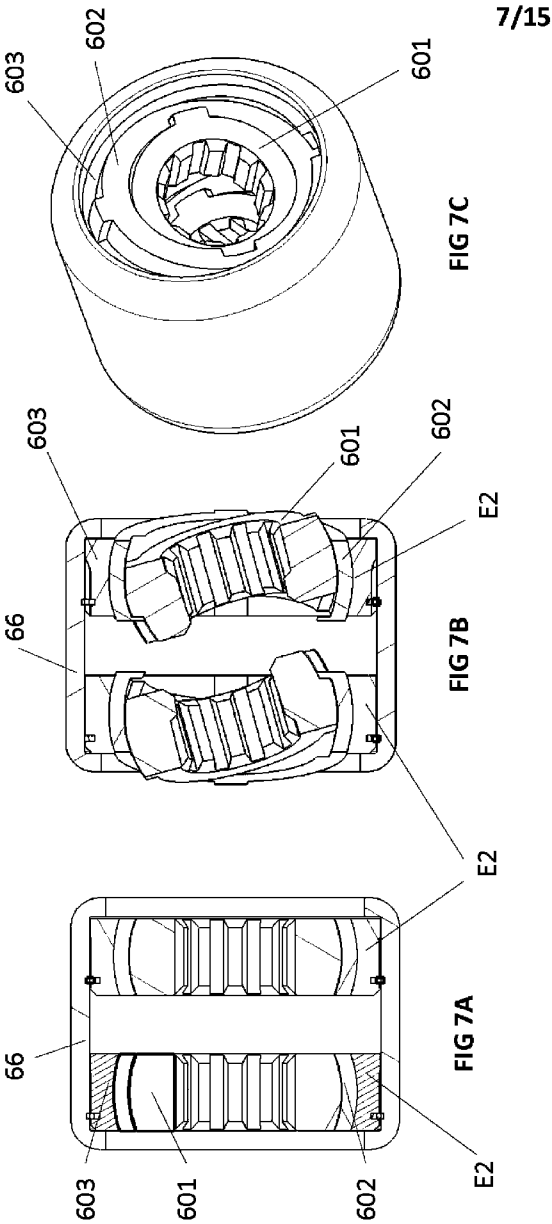
[Fig.]



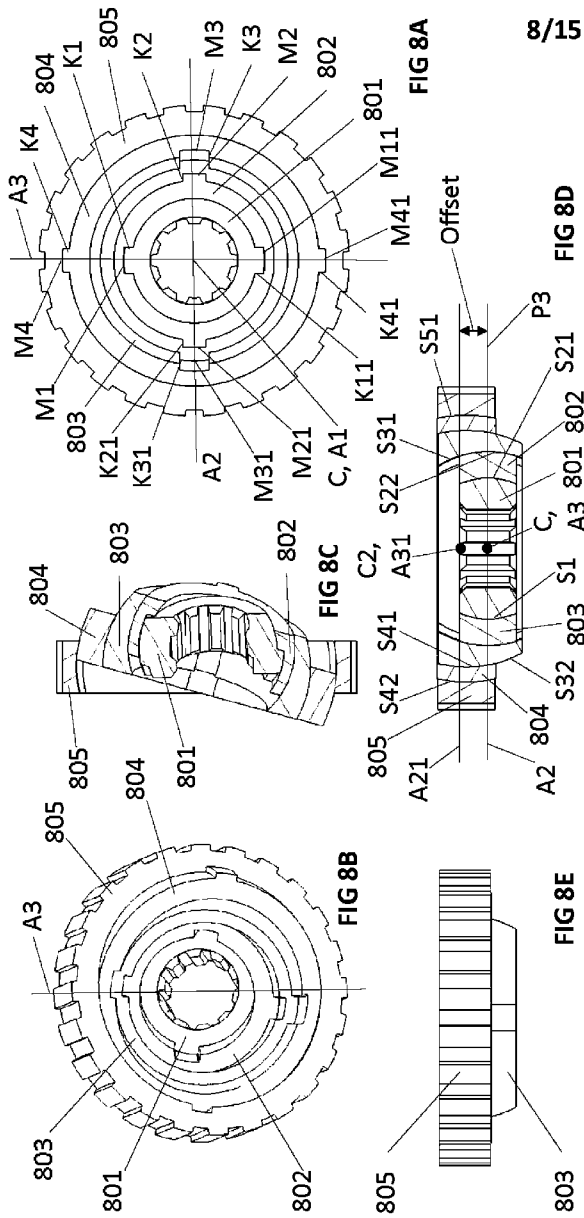
[Fig.]



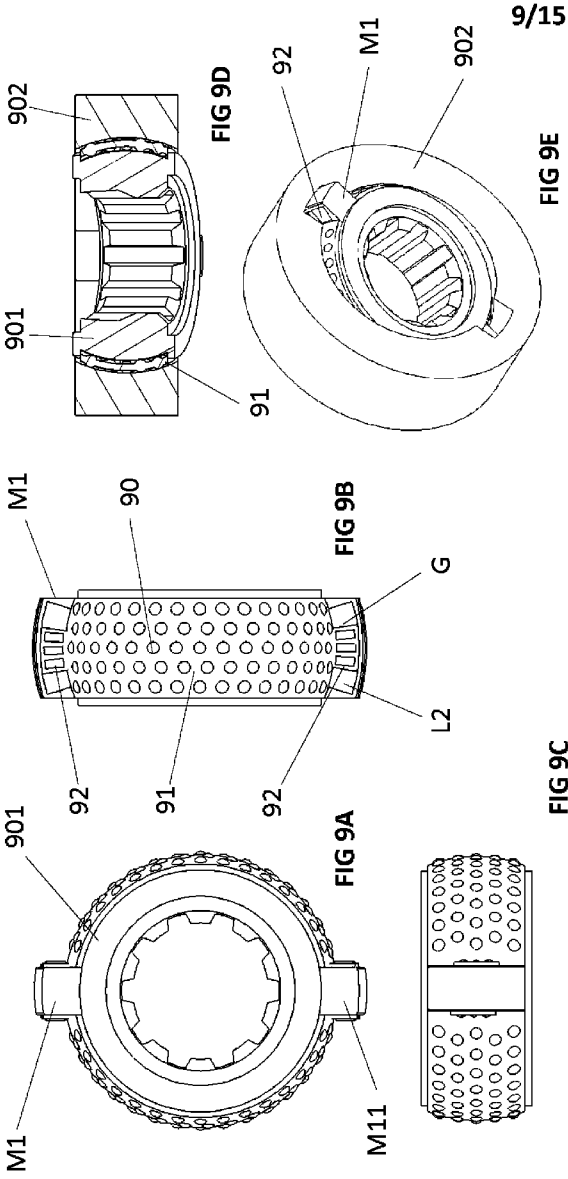
[Fig.]



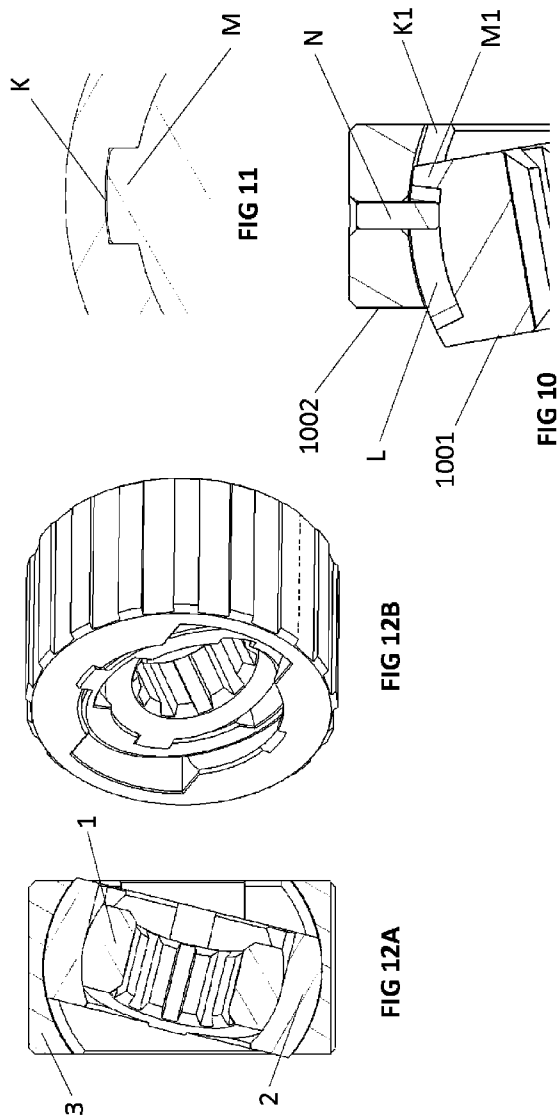
[Fig.]



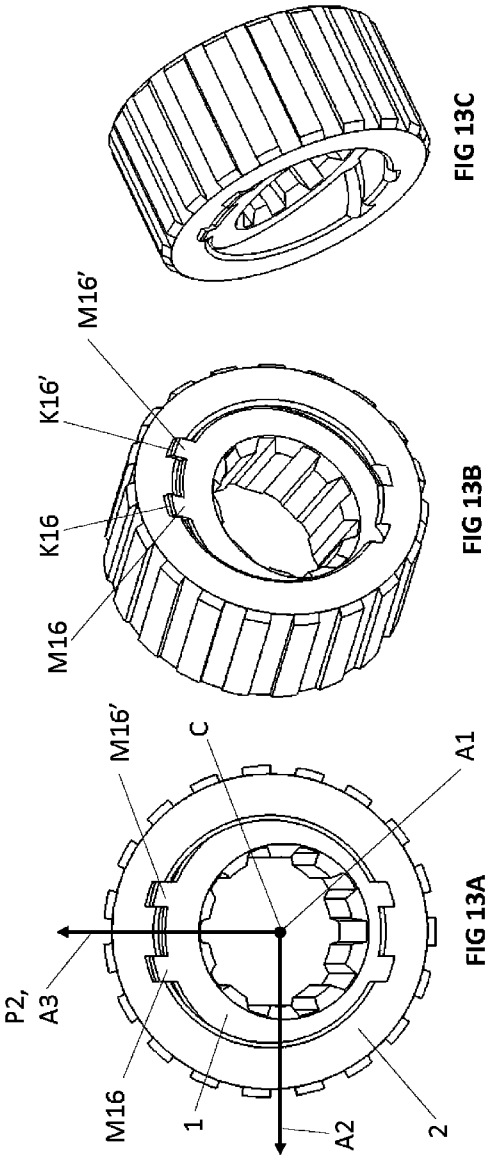
[Fig.]



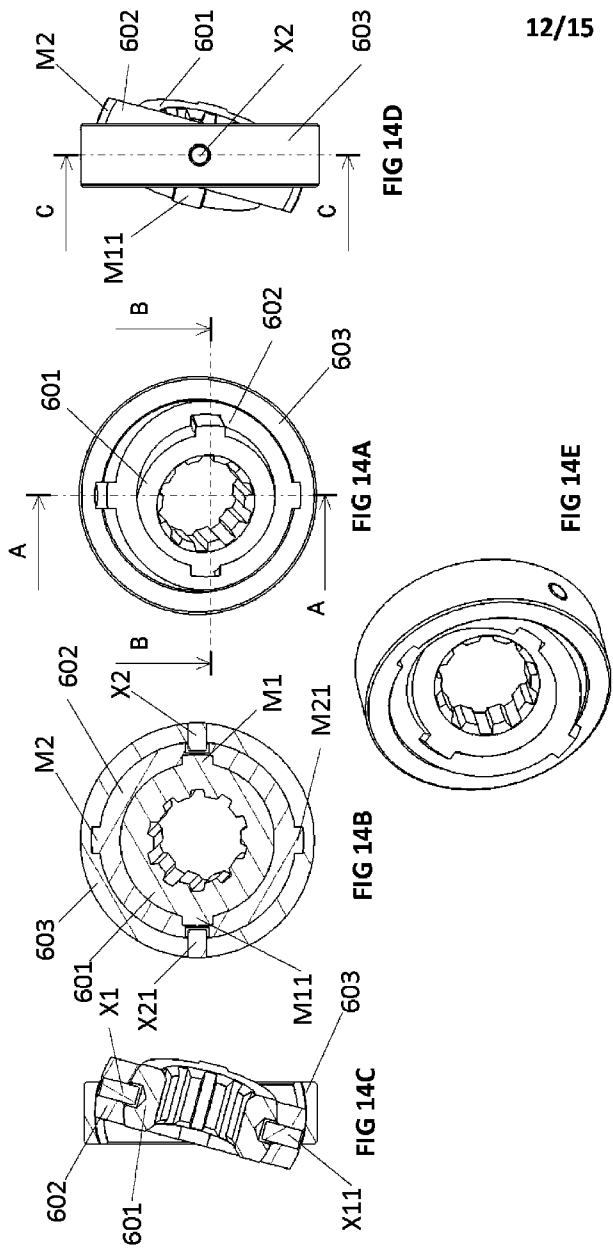
[Fig.]



[Fig.]



[Fig.]



[Fig.]

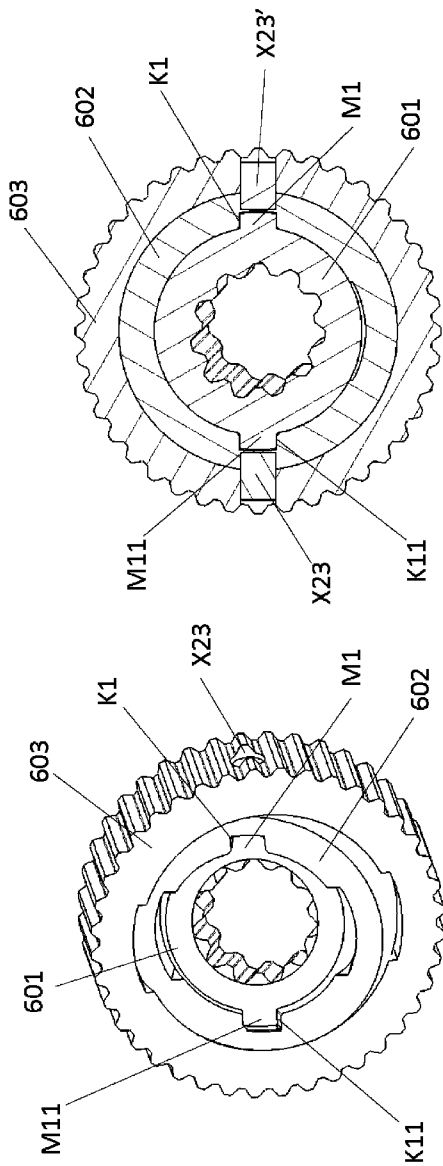
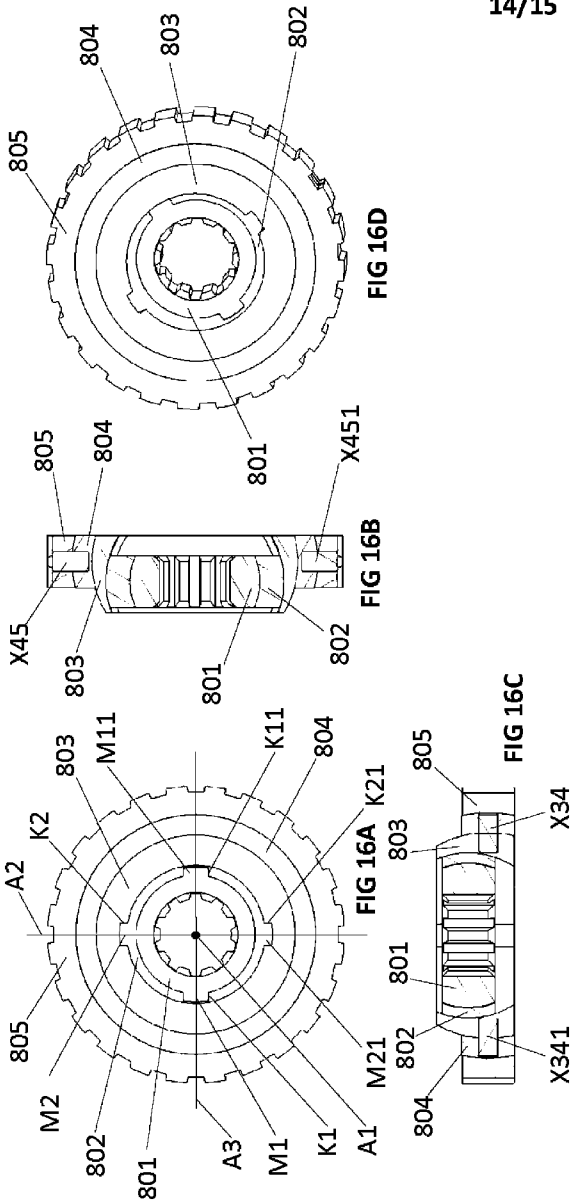


FIG 15B

FIG 15A

[Fig.]



[Fig.]

