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1 564 105

(54) IMPROVEMENTS RELATING TO ASSEMBLIES INCLUDING ELECTRICAL INTERCONNECTIONS

(71) We, FERRANTI LIMITED a Company registered under the Laws of Great Britain of Hollinwood in the County of Lancaster, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to assemblies including electrical interconnections, and in particular to such assemblies each including two members capable of limited relative rotation about a common axis, and an electrical interconnection secured to two positions, one on each of the two members.

Limited relative rotation about the common axis is where relative rotation between the two members is permitted over a range less than 360°. The mean relative orientation of the two members is where, assuming one member to be fixed, the other member is capable of the same permitted range of rotation, less than 180°, in each of two possible directions of rotation. At the limits of relative rotation of the two members, and again assuming one member to be fixed, the other member is capable of rotation only in one direction.

In known forms of such assemblies it is usual for the permitted range of relative rotation of the two members to be considerably less than 360°.

Each known form of flexible conductor strip has a mean width greater than its thickness, in relation to the axis of the strip extending between the securing positions on the two members. Usually under normally encountered operating conditions the strip is inextensible. Such a strip may have a single conductor or a plurality of insulated conductors. If the strip has a plurality of conductors, the conductors extend substantially parallel to each other along the length of the strip. A strip of the form referred to above is advantageous when the electrical interconnection is required to have a plurality of conductors, because its shape facilitates the connection of terminals or other conductors to the electrical interconnection. Such a strip may be in the form of a flexible printed circuit having an insulating covering for the conductors. In any event, each conductor of the electrical interconnection is covered with insulating material, but it is desirable that the arrangement of the assembly is such that the electrical interconnection does not inadvertently touch any other part of the assembly.

It is an object of the present invention to provide a novel, and simple, form of an assembly of the kind referred to above, and having an electrical interconnection including a flexible conductor strip with a mean width greater than its thickness in relation to the axis of the strip extending between the securing positions on the two members.

According to the present invention an assembly includes two members capable of limited relative rotation, over a range less than 360°, about a common axis, and an electrical interconnection including at least one flexible conductor strip secured to two positions, one on each of the two members, the two securing positions being in different planes spaced apart along the common rotational axis, the planes being normal to the common rotational axis, in relation to the axis of the strip extending between said securing positions on the two members, the strip having a mean width greater than its thickness, the axis of the strip extends to a point at least adjacent to the common rotational axis, projections of the two portions of the axis of the strip between the two securing positions and the part of the strip furthest from the securing positions, onto a plane normal to the common rotational axis, extend radially from the common rotational axis, and with the members at one particular orientation in relation to each other, intermediate between their limits of relative rotation, the axis of the strip lies in a plane including the common rotational axis.

Said one particular relative orientation of the two members may be the mean relative orientation (as hereinbefore defined), of the two members.

The flexible strip may be secured to the two members in any convenient way, for example, being clamped to the members.

Relative rotation of the two members from said one particular relative orientation causes the axis of the strip extending between said securing positions on the two members to twist.

Conveniently, the two members may be apertured, there being a common central bore through the members, and the strip extends within the common central bore. The common central bore may have any convenient shape in section. The axis of the flexible conductor strip may enter the common central bore at points spaced from the walls defining the bore, because of the finite width of the strip. The two apertured members may provide a bearing casing. Further, one of the two members may carry the coil of an electrical motor connected to the electrical interconnection. Thus, the two members may be associated with gyroscope gimbals, and the electrical motor is a torque motor to control a gyroscope gimbal. Usually gyroscopes, in operation, are to be subjected to high accelerational forces, and in an assembly according to the present invention, having a flexible conductor strip with a mean width greater than its thickness, is advantageous because the strip easily can be accommodated, but the bent strip has inherent rigidity in any plane including the common rotatonal axis of the member 5. Further, it is desirable that the torque motor is not required to provide greater torque than is necessary in order to cause relative rotation of the members, and hence resilient deformation of the flexible strip caused by relative rotation of the members should be as low as possible.

It is self-apparent that the flexible strip should not be permanently deformed. The strip deforms resiliently by cyrling about the axis of the strip between the two securing points.

Resilient deformation of the strip by relative rotation of the two members may be less than otherwise would be the case by having an arrangement in which the axis of the strip extends between said two securing positions on the two members in a smooth curve when the axis of the strip lies in a plane including the common rotational axis of the members.

The resilient deformation of the strip is less than otherwise would be the case if the axis of the strip extends to a point at least adjacent to the common rotational axis of the two members, because the axis of the strip extends to substantially the same point for any permitted relative orientation of the members.

Conveniently, said securing positions on the two members are substantially equally spaced from the common rotational axis of the members, and there are two equal portions of the axis of the strip between the two securing positions and the part of the strip furthest from said securing positions.

The limits of relative rotation of the two members may be defined by comprising the relative orientations of the two members in which the edges of the strip become straight lines due to relative rotation of the two members. By avoiding the edges of the strip becoming straight lines substantial resilient, or any permanent, deformation of the strip is avoided.

In order to avoid substantial resilient, or any permanent, deformation of the strip, whilst the permitted range of relative rotation of the two members easily may be greater than 180°, the permitted range should not approach 360°. Usually the limits of relative rotation are defined by at least one stop part of one of the two members, the stop parts either engaging the other member or engaging an anchorage, for example, before the edges of the strip becomes straight lines due to relation rotation of the two members.

It may be possible to arrange that the part of the strip furthest from said two securing positions extending in a straight line, i.e. is not curled about the longitudinal axis of the strip, with the two members midway between their mean relative orientation the strip being curled in the opposite direction to that when the two members are at either of their limits of relative rotation.

The longitudinal symmetrical axis of the strip may comprise the axis extending between said securing positions on the two members.

A plurality of flexible conductor strips, and especially ribbon-shaped strips may be provided to comprise the required electrical interconnectiohn, the flexible strips being substantially uniformly distributed about the common rotational axis of the two members. It is essential that the constituent strips do not touch each other, and thus no constituent strip is capable of extending to the common rotational axis of the members. A convenient arrangement is one in which two flexible conductor strips are provided, the securing positions for the strips being diametrically opposite to each other on the member 5 in relation to the common rotational axis of the members. Usually the plurality of conductor strips are substantially identical.

One specific embodiment according to the present invention will now be described, by way of example, with reference to the accompanying drawings, in which

Figure 1 shows a sectional side view of an assembly having an electrical interconnection secured to two relatively rotatable members, comprising parts of gyroscope gimbals.

Figure 2 shows an end view of the gimbals of Figure 1, the members being in their mean relative orientation intermediate between the limits of their relative rotation, and

Figure 3 is as Figure 2, but with the members rotated to one of their limits of relative rotation.

As illustrated, annular members 10 and 11 are associated with gimbal frames of a gyroscope, not otherwise shown. The members 10 and 11 provide a bearing casing, and are relatively rotatable by means of a ball bearing 12 about a common rotatonal axis 13. Two groups of lead 14 and 15 are connected to corresponding groups of leads 16 and 17 by way of an electrical interconnection secured to the two members 10 and 11, and comprising two identical flexible conductor strips 18 arranged. The securing positions for the two strips are diametrically opposite to each other in relation to the common rotational axis 13 of the members 10 and 11. Each strip extends to a point adjacent to the common rotational axis 13. The strips 18 are ribbon shaped each havig a width greater than its thickness. Each strip 18 has a uniform thickness, and a substantially uniform width, the length of the strip being greater than its width. The strips 18 comprise flexible printed circuits having a plurality of substantially parallel conductors 19 (Figures 2 and 3) enclosed within insulating material. In each strip 18 the conductors 19 extend substantially parallel to the longitudinal axis 20 of symmetry of the strip.

Clamps 21 hold the ends of the flexible strips against the outer face 22 of the member 10, and against the outer face 23 of the member 11. The longitudinal axis 20 of symmetry of each strip can be considered as extending from the clamps 21, the clamps 21 being considered to be at the securing positions for the strips on the two members 10 and 11.

There is a common central bore 24 through the annular members 10 and 11, and the strips extend between the clamps 21 through the bore 24, each strip being bent. Projections of the two portions of the axis of each strip between the two associated securing positions and the part of the strip furthest from the securing positions, onto a plane normal to the common rotational axis 13, extend radially from the common rotatonal axis.

The groups of leads 14, 15, 16 and 17 are soldered to the conductors 19 of the strips, the soldered joints being within a slot 25 in each clamp. Thus, the flexible strip is clamped on each side of the soldered joints.

A coil 26 of a torque motor is carried on the member 11, and is connected to two of the conductors 19.

Limited relative rotation about the common axis 13 is permitted between the members 10 and 11, over a range less than 360°, and in the illustrated embodiment this range is substantially 180°. The mean relative orientation of the members 10 and 11 is where, assuming one member to be fixed, the other member is capable of the same permitted range of rotation, substantially 90°, in each of two possible directions of rotation.

At the limits relative rotation of the members 10 and 11, and again assuming one member to be fixed, the other member is capable of rotation only in one direction. The limits of relative rotation are defined by a stop part 27 on the member 11 abutting against a co-operating, semicircular part 28 on the member 10 when the members are at their limits of relative rotation.

In one particular relative orientation of the members 10 and 11, as shown in Figure 1 and 2, and which in the illustrated embodiment is their mean relative orientation, the longitudinal axis 2o of symmetry of each each stip 18 lies in a plane including the common rotational axis 13 of the members. Relative rotation of the two members from their mean relative orientation causes the longitudinal axis 20 of symmetry of each strip to twist.

When the two members are at either of the limits of relative rotation, as shown in Figure 3, it will be seen that the edges of the strips are not straight lines.

Whilst it is essential that the strips do not touch each other, implying that the strips cannot extend to the common rotational axis 13 of the members, they may conveniently extend to adjacent to the axis 13.

The limits of relative rotation of the two members may be defined in various ways, there being many possible arrangements instead of providing stop parts mounted on the members, as referred to above. The limits of relative rotation may be defined by when the edges of the strips become straight lines. However, substantial resilient, or permanent, deformation of the strips may occur when their edges become straight lines.

Further, in order to avoid substantial resilient, or any permanent, deformation of each strip it is desirable that the permitted range of relative rotation of the members should not approach 360°, although it is possible easily to avoid deformation and have a permitted range of relative rotation of the members greater than 180°.

Conveniently, as shown, the clamps 21 are substantially equally spaced from the common rotational axis 13 of the members, and there are two equal portions of the axis of the strip between the two securing positions and the part of the strip furthest from the securing positions.

Whilst any permanent deformation of each strip should be avoided, it is also desirable to avoid substantial resilient deformation of the strip in order that the torque required to cause the relative rotation of the members is as small as possible. This is particularly so when the assembly of the members 10 and 11 and the electrical interconnection secured to the members are part of a gyroscope gimbal arrangement. Thus, a torque motor is required to provide as small a torque as will cause relative rotation of the members.

Resilient deformation of each strip may be made less than otherwise would be the case by ensuring that the longitudinal axis of the symmetry of the strip extends in a smooth curve, as shown in Figure 1, and at least when within the common central bore 24 of the members.

Resilient deformation of each strip may be less than otherwise would be the case by the longitudinal axis of symmetry of the strip extending to a point adjacent to the common rotational axis 13 of the members, as illustrated. Hence, each axis 20 extends to substantially the same point for any permitted relative orientation of the members 10 and 11.

The strip deforms resiliently by curling about the longitudinal axis of symmetry of the strip. In the figures no such resilient deformation is shown.

The gyroscope may have any convenient construction, for example, as described in Inertial Guidance Engineering by M. Fernandez and G.R. Macomber, Prentice - Hall Inc. 1962.

Usually gyroscopes, in operation, are subjected to high accelerational forces, but the clamped strips, comprising electrical interconnection within assemblies according to the present invention, have inherent rigidity in any plane including the common rotational axis of the members.

It will be appreciated that the electrical interconnection described above can be modified in various ways. For example each flexible strip used could be a single flat conductor, or a plurality of insulated conductors arranged to be a coplanar i.e. a flat cable. If the strip has a plurality of conductors, the conductors extend substantially parallel to each other along the length of the strip.

The number of conductors per flexible strip could be increased by providing conductors on the outside of the insulation, suitable insulating means being provided to isolate the conductors from the surface to which the ends of the strip are clamped.

It may be possible to arrange that the part of the strip furthest from said two securing positions extends in a straight line, i.e. is not curled, with the two members midway between their mean relative orientation and either limit of relative rotation of the two members, the strip being curled in the opposite direction with the two members at their mean relaton orientation to that when the two member-s are at their limits of relative rotation.

The electrical interconnection may comprise any convenient plurality of strips substantially uniformly distributed about the common rotational axis of the members 10 and 11. It is essential that the constituent strips are not capable of touching each other.

Alternatively, only one strip may be provided, and this strip may extend beyond the common rotational axis 13 of the members 10 and 11, although advantageously it extends to a point adjacent to the axis 13.

Especially if one strip, or two diametrically opposite strips, are proided the strips may have any convenient shape in plan. However, it is required that the mean width of each strip is greater than the thickness. The thickess need not be uniform.

Usually under normally-encountered conditions each strip is inextensible.

A further modification facilitating assembly, and improving reliability, comprises continuing the flexible strip beyond the clamps in place of the soldered leads.

The strips may be secured to the members in any convenient way, for example, a pin and socket connector might be provided at the point at which each flexible strip is secured so removing the need for soldered joints and clamps.

The assembly according to the present invention may not be part of a gyroscope.

The relatively rotatable members may have any convenient shape, and may not provide a bearing casing, or indeed have a common central bore. The common central bore may be formed by the members in any convenient way; and each strip may not extend completely through the common central bore. The central bore of either apertures members may have any convenient shape in section. The axis of the flexible conductor strip may enter the common central bore at points spaced from the walls defining the bore, because of the finite width of the strip.

The members may not be apertured, and may be spaced apart with the electrical interconnection extending therebetween.

WHAT WE CLAIM IS:-

1. An assembly including two members capable of limited relative rotation, over a range less than 360°, about a common axis, and an electrical interconnection including at least one flexible conductor strip secured to two positions, one on each of the two members, the two securing positions being in different planes spaced apart along the common rotational axis, the planes being normal to the common rotational axis, in relation to the axis of the strip extending between said securing positions on the two members, the strip having a mean width greater than its thickness, the axis of the strip extending to a point at least adjacent to the common rotational axis, projections of the two portions of the axis of the strip extending to a point at least adjacent to the common rotational axis, projections of the two portions of the axis of the strip between the two securing positions and the part of the strip furthest from the securing positions, onto a plane normal to the common rotational axis, extend radially from the common rotational axis, and with the members at one particular orientation in relation to each other, intermediate between their limits of relative rotation, the axis of the strip lies in a plane including the common rotational axis.

2. An assembly as claimed in claim 1 in which said one particular relative orientation of the two members is the mean relative orientation (as hereinbefore defined), of the two members.

3. An assembly as claimed in claim 1 or claim 2 in which the two members are apertured, there being a common central bore through the members, and the strp extends within the common central bore.

4. An assembly as claimed in claim 3 in which the two apertured members provide a bearing casing.

5. An assembly as claimed in claim 3 or clam 4 in which one of the two members carries the coil of an electrical motor connected to the electrical interconnection.

6. An assembly as claimed in claim 5 in which the two members are associated with gyroscope gimbals, and the electrical motor is a torque motor to control a gyroscope gimbal.

7. An assembly as claimed in any one of the preceding claims in which the limits of relation rotation of the two members are defined by at least one stop part on one of the two members.

8. An assembly as claimed in any one of the preceding claims in which the axis of the strip substantially wholly extends between said two securing positions on the two members in a smooth curve when the axis of the strip lies in the plane including the common rotational axis of the members.

9. An assembly as claimed in any one of the preceding claims in which the part of the strip furthest from said two securing positions extends in a straight line with the two members midway between their mean relative orientation and either limit of relative rotation f the two members.

10. An assembly as claimed in any one of the preceding claims in which said securing positions on the two members are substantially equally spaced from the common rotational axis of the members, and there are two equal portions of the axis of the strip between the two securing positions and the part of the strip furthest from said securing positions.

11. An assembly as claimed in any one of the preceding claims in which the longitudinal symmetrical axis of the strip comprises the axis extending between said securing positions on the two members.

12. An assembly as claimed in any one of the preceding claims in which a plurality of flexible, ribbon-shaped conductor strips are provided, to comprise the required electrical interconnction, the flexible strips are substantially uniformly distributed about the common rotational axis of the two members.

13. An assembly as claimed in claim 12 in which two flexible conductor strips are provided, the securing positions for the two strips being arranged diametrically opposite to each other on the members in relation to the common rotational axis of the members.

14. An assembly as claimed in claim 12 or claim 13 in which the plurality of conductor strips are substantially identical.

15. An assembly including two members capable of limited relative rotational about a common rotational axis and an electrical interconnection at least including a flexible conductor strip secured to positions on the two members spaced from the common rotational axis, and the assembly being substantially as described herein with reference to the accompanying drawings.

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1564105 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1.

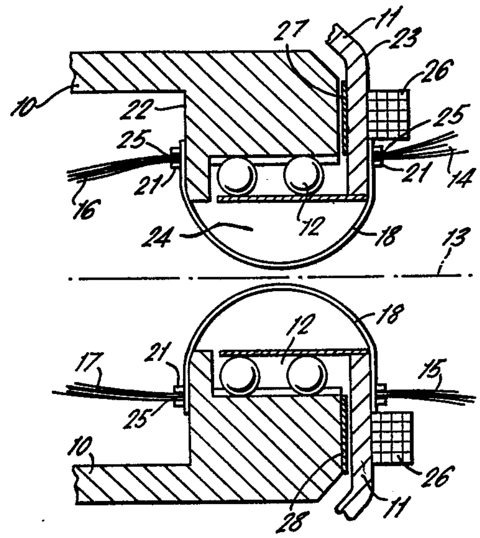

FIG. 2.

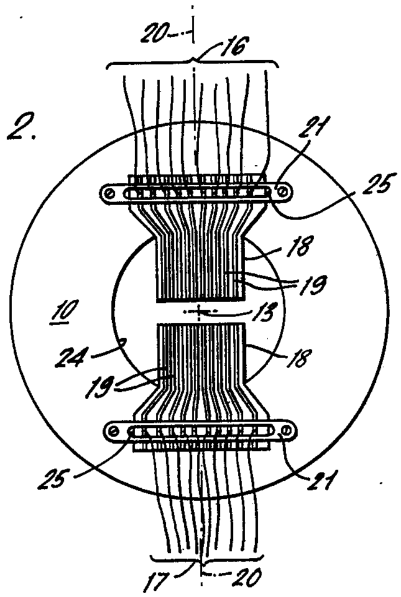

FIG. 3.