June 2, 1970 I. A. DUCK 3,515,006

SPRING PIVOTS

Filed Feb. 24, 1966 4 Sheets-Sheet 1

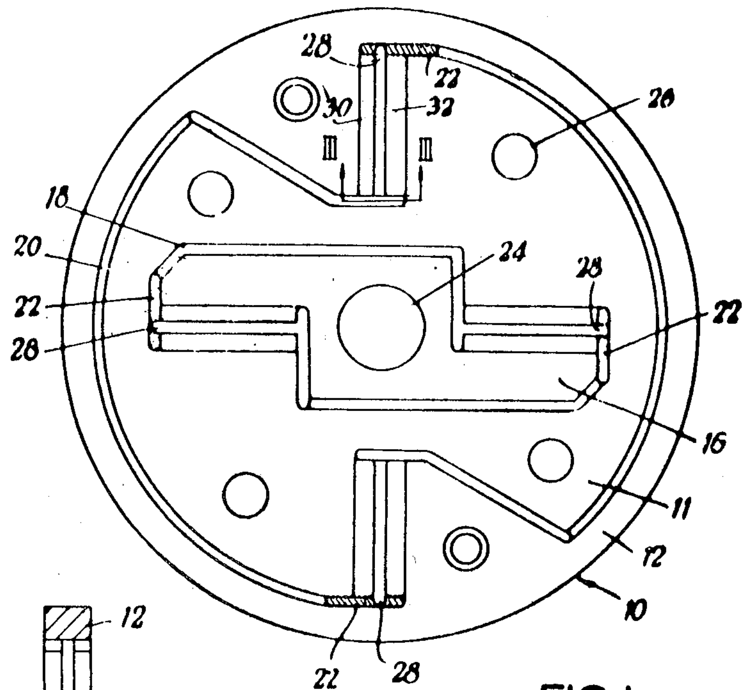

FIG. 1

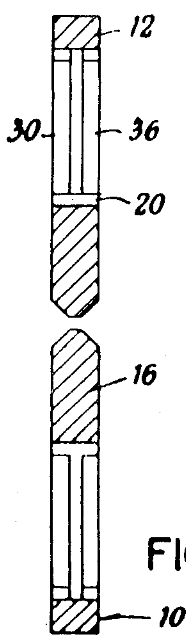

FIG. 2

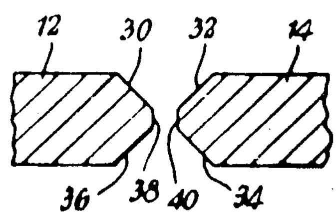

FIG. 3

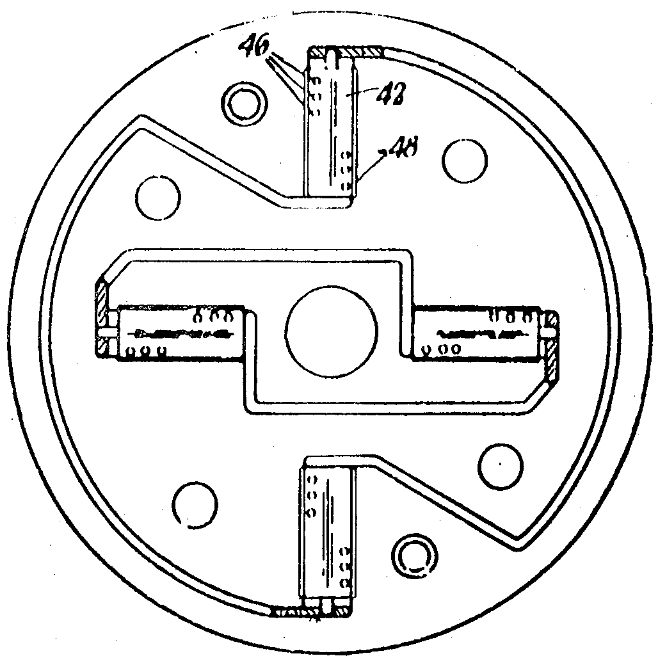

FIG. 4

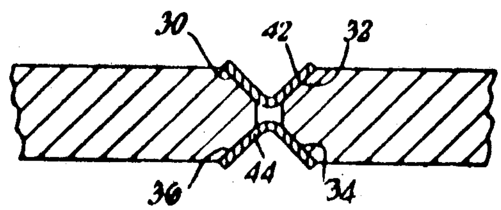

FIG.5

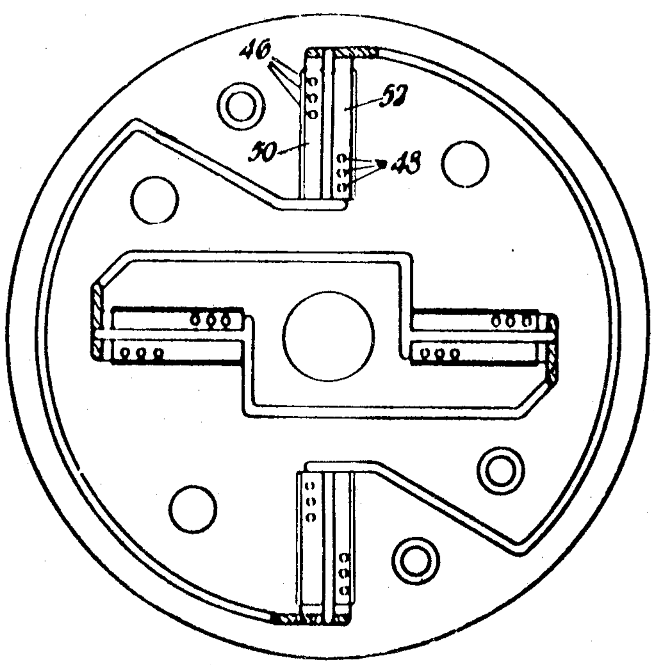

FIG.6

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SPRING PIVOTS

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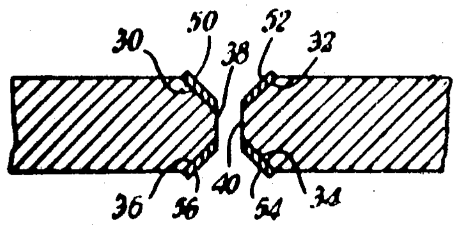


FIG.7

FIG.9

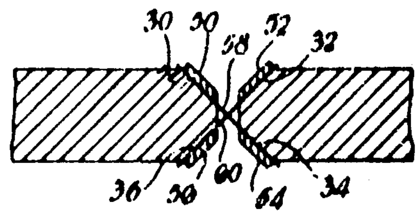
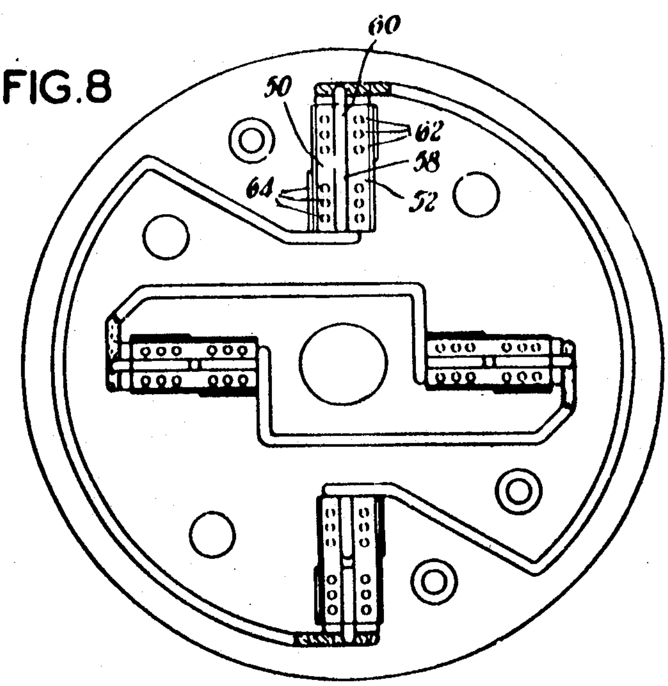


FIG.8



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SPRING PIVOTS

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Int. Cl. G01c *19/02*
U.S. Cl. 74—5 8 Claims

ABSTRACT OF THE DISCLOSURE

Flexural spring pivots for use in precision instruments such as gyroscopes and particularly dynamically tuned free rotor gyros are provided wherein each of said pivots comprise a pair of spring strips which cross on the pivot axis and extend across a gap separating the parts. The strips are secured between the parts and overlying clamping elements. The effective dimension of each strip can be accurately determined by removal of material from the elements before insertion of the strips, to align edges of the elements with the sides of the gap. The elements can be angle strips secured to tapered faces of the parts adjacent the gap and divided as part of the edge adjustment step. The gap can be a slot formed in a single piece of metal wherein the slot is extended after securement of the spring strips to divide the piece into the parts.

The invention relates to flexural spring pivots for use where great precision is essential, for example, in gyroscopes. The invention also relates to gyro rotor assemblies incorporating the flexural spring pivots.

A gyroscope rotor should ideally be mounted in such a way that any kind of twisting or translation of its housing or other support has no disturbing effect on the orientation of the rotation axis of the rotor. In practice, there are obvious difficulties in supporting a mass and applying a rotational drive to it without such disturbances being applied. However, in an article in "Control Engineering," June 1964 by Edwin W. Howe and Paul H. Savet entitled, "The Dynamically Tuned Free Rotor Gyro," there is explained the basis of a suspension arrangement for a gyro rotor by which the rotor is theoretically decoupled from its suspension. The arrangement proposed employs a gimbal ring between a shaft to which a rotational drive is applied and an annular mass constituting the gyro rotor. With this arrangement, the motor is carried by the housing and any radial unbalances are averaged out each rotation. The inertial effects of the gimbal ring on the rotor act as a dynamic negative spring restraint, tending to cause a conical precession of the spin axis in the same direction as the direction of rotation of the rotor; the magnitude of this dynamic restraint increases with increase of rotor speed. On the other hand, spring suspensions can be made with a positive spring restraint, which would cause a conical precession of the spin axis in the direction opposite to that of the rotor. By suitably combining these effects, they can be made to cancel one another and the precessional period can be brought theoretically to infinity.

In producing a suitable gyro rotor assembly as thus proposed, pairs of flexural spring pivots have to be secured on orthogonal diameters between the rotor and the gimbal ring and the gimbal ring and the shaft respectively. The machining and assembly of the various parts is required to be very accurate as even an extremely small misalignment between the pairs of pivots would introduce abnormal stresses in the flexural springs, which would confer undesirable nonlinear performance characteristics to the gyro.

The invention thus has as a major object the provision of an assembly incorporating an advantageous form of flexural spring pivot arrangement. It is also a major object to provide a convenient method of producing such an assembly. Although particularly applicable to assemblies for use as dynamically tuned free rotor gyros, the invention is not so limited and may be applied in other contexts, for example, to accelerometers.

The invention accordingly provides an assembly comprising two portions and flexural spring pivot means extending therebetween, the flexural spring pivot means comprising a plurality of leaf spring members integral with or secured directly to the portions.

The invention also provides a gyro rotor assembly comprising an outer portion, surrounding an intermediate portion, an inner portion surrounded by the intermediate portion, first and second pairs of aligned flexural spring pivot means between the outer and intermediate portions and between the inner and intermediate portions respectively, the axes on which the two pairs of flexural spring pivot means are aligned being perpendicular, and the flexural spring pivot comprising leaf spring members secured directly to the respective portions.

The invention also provides a method of producing such assemblies, in which positive location of the portions thereof is assured. The portions may be formed separately and then positioned on a jig or like means, a gap or slot provided between them, the leaf spring members being secured, as by spot welding, across the slot. The portions may instead be relatively located by forming them from a single piece of material, for example, of beryllium copper. A slot can be made in the piece and the spring pivot means secured across the slot, which is subsequently extended to separate the portions.

The outer portion of the gyro rotor assembly is of course employed as the actual rotor, the intermediate portion functioning as a gimbal ring between the rotor and the inner portion by which the assembly is mounted on a driving shaft.

By the method of the invention, inherent abnormal stresses in the springs can be avoided, so that a rotor assembly of very high accuracy is obtained quickly and economically.

Formation of spring pivots in the illustrative gyro rotor assembly in accordance with the invention is described below with reference to the accompanying drawings.

In the drawings:

FIGS. 1 and 2 are axial and edge views respectively of a disc after the first stage of manufacture of an embodiment of an assembly in accordance with the present invention;

FIG. 3 is a section on a larger scale on the line III—III of FIG. 1;

FIGS. 4 and 5 correspond to FIGS. 1 and 3, respectively, but show a second stage of manufacture;

FIGS. 6 and 7 likewise correspond to FIGS. 1 and 3, a third stage having been performed;

FIGS. 8 and 9 again correspond to FIGS. 1 and 3, but relate to a fourth stage of manufacture.

As shown in FIGS. 1 and 2, a single piece of material **10** initially having the form of a flat circular disc is in the process of division into a rotor **12**, a gimbal ring **11** and a central mounting piece **16**. At the stage shown in these two figures, major portions of inner and outer slots **18** and **20** have been cut through the disc **10**, as by engraving. The outer slot **20** has major portions on a circle concentric with the disc **10**. These portions are later to be extended by the cutting through of portions **22** which extend at right angles to a diameter of the disc. Portions **28** extending inwardly on this diameter from the uncut portions **22** run into portions parallel to the portions **22**, which portions connect to the other ends of respective major portions of the slot **20**. The inner slot **18** also has portions **28** which extend along a diameter at right angles to that previously mentioned and which run into portions extending across this second diameter, the outer two of which, marked **22**, are not at this stage cut through. The four portions **28** are equal length and are equally spaced from the disc centre. The major portions of the slot **18** extend parallel to the second diameter, being connected at their ends to the portions transverse to this. Because the two portions **22** have yet to be removed to complete each slot, the disc is still an integral piece. A centre hole **24** for receiving a driving shaft on which the assembly is is to be mounted, and outer holes **26** have also been cut through the disc **10** at this stage. The holes **26** are for the reception of suitable weights.

Over the two radially extending portions **28** of each of the slots **18, 20**, the edges on both sides have been symmetrically tapered. As appears more clearly from FIG. 3, the tapered faces **30, 32** at the upper side, (as shown in this figure) are at right angles and each is parallel to the face of the faces **34, 36** on the lower side of the disc, which is at the other side of the slot. Opposed central portions **38, 40** of the original slot walls remain between the tapered faces.

Each of the four portions **28** is to accommodate a pair of strip springs which will constitute the only connections between the rotor **12**, the ring **11** and the mounting piece **16**. The following description will for convenience refer to only one portion **28** but it will be understood that all four portions are treated similarly, each stage of the operation being preferably preformed on all the portions before the next is begun.

As will appear from FIGS. 4 and 5, the second stage comprises the securement of clamping members **42, 44** to the tapered faces **30, 32, 34** and **36**. Each of the clamping members **42, 44** is a length of right-angled metal strip, suitably of stainless steel. The clamping member **42** is secured by spot welding at **46** to the upper face **30** at the outer end, radially of the disc **10**, and to the upper face **32** at the inner end by spot welding at **48**. The clamping member **44** is spot welded to the lower face **36** at the radially inner end to the lower face **34** at the outer end. Although three spot welds are indicated in the drawings, the clamping members can be fixed in any suitable way which leaves at least half of the length of the clamping member unsecured to the tapered faces.

The next stage, shown in FIGS. 6 and 7 comprises separation of the two flanges of each of the clamping members **42, 44** by removal, as by engraving, of the centre part of the member forming the right angle bend. The member **42** is thus divided into clamping strips **50** and **52** secured on the faces **30** and **32**, respectively, and divides the member **44** into strips **54** and **56** on the faces **34** and **36**, respectively. The removal of material is carried outwards from the angle of the members until the newly formed edges of the separated clamping strips are flush with the parallel opposed wall portions **38, 40** of the slot portion **28**, as shown in FIG. 7. As will later appear, the spacing of these edges determines the effective width of the spring strips, which is crucial to the performance of the assembly. It is the major advantage of the method of the invention that it allows the location of these edges to be determined by removal of portions of fixed clamping members, instead of by the positioning of a finished member; the former step can be performed with much greater accuracy.

Insertion of spring strips **58, 60**, as shown in FIGS. 8 and 9, now follows. Spring **58** is slid between the strip **50** and the face **30**, at their radially inner ends, and across the slot portion **28** to enter between the face **34** and the clamping strip **54**. Similarly, the spring **60** is slid between the face **32** and the strip **52**, across the slot portion **28** to between the face **36** and the strip **56** at the radially outer ends. The springs are then secured, conveniently again by spot welds, the spring **60** being welded at **62** and the spring **58** being welded at **64**; welds are also made at the other side of the disc **10** to hold the springs **58** and **60**, respectively, between the strip **54** and the face **34** and between the strip **56** on the face **36**. The ends of the strip springs **58, 60** are then trimmed off, as by grinding.

Finally, the portions **22** are cut to complete the slots **18** and **20**, leaving the rotor **12**, the gimbal ring **11** and the mounting portion **16** connected only by the four sets of spring strips **58** and **60**.

Each clamping strip could of course be a separate member originally, instead of being cut from one flange of an angled strip, before its precisely located edge is formed. Moreover, the method of the invention can be modified by completing the slots **18** and **20** before the welding operations. The portions are then relatively positioned as shown in the figures by any suitable supporting arrangement, conveniently one employing pins for reception in the holes **24** and **26**. It will be appreciated that the advantageous location of the edges determining the effective width of the leaf spring strips by removal of fixed material will still be obtained.

It will be appreciated that the spring elements will normally be designed so that they will have a load carrying capacity as high as possible and a flexural stiffness as low as possible. The width of each spring leaf should be large but choice is limited by the desirability of a compact arrangement and the need, in the embodiment described, to arrange two springs on each half of a diameter between the two portions they connect. Consequently, a choice is made of a convenient ratio of thickness to length which affords a ratio of flexural stiffness to load carrying capacity which is as low as possible.

Also in accordance with the present invention, the gyro rotor assembles can incorporate spring suspension systems which have elastic symmetry, that is, which are isoelastic, or, alternatively, which are nonisoelastic by a selected amount. This condition can be achieved in the embodiment described by altering slightly the angle between the leaves of the spring pairs from the perpendicular arrangement shown.

It will be appreciated that the embodiment of the invention specifically described can be modified, and the invention otherwise embodied, within the scope thereof which is defined in the following claims.

What is claimed is:

1. A method of assembling a pair of metal members and at least one metal strip in precisely determined relative positions for the strip to function as a flexural spring pivot between the members, the method comprising the steps of securing to each of the members a metal clamping element with a portion of the element overlying a surface portion of the member to which the strip is to be secured; removing material from at least one of said clamping elements to determine precisely the position of the adjacent edges thereof; placing the strip between said surface portions of the members and said portions of the clamping elements; and securing together said clamping elements, said metal strip and said members.

2. A method as claimed in claim **1** additionally comprising the steps of providing surface portions of the members by symmetrically tapering the edges, and welding the metal strip and a second metal strip to the tapered edges in cross-formation to function as a crossed flexural spring pivot between the members.

3. A method as claimed in claim **2** additionally comprising the steps of welding a pair of angled elements to the surface portions of the members to constitute the clamping elements, and removing material from the angled elements to divide each into the two clamping elements.

4. A method as claimed in claim **1** wherein the metal members are initialy integral and additionally comprising the steps of assembling the metal strip across a slot and thereafter extending the slot to separate the members.

5. A method as claimed in claim 2 additionally comprising the steps of securing two further strips to the members in a like manner to function as a second crossed flexural spring pivot means betwen the members and aligning the axes on which the strips of the two spring pivot means are crossed.

6. A method as claimed in claim 5 wherein the aligned pair of spring pivot means is secured so that they constitute one of two pairs of spring pivot means aligned on perpendicular axes in a gyro roto assembly having an outer member, a gimbal member, and a mounting member, the outer member surrounding the gimbal and mounting members, one of the aligned pairs of spring pivot means connecting the outer and gimbal members, and the other of the said pairs of spring pivot means connecting the gimbal and the mounting members.

7. A gyro rotor assembly comprising a rotor member, a gimbal member; and a mounting member, the rotor member surrounding the gimbal and mounting members; a first pair of aligned flexural spring pivot means connecting the rotor member and the gimbal member; a second pair of aligned flexural spring pivot means connecting the gimbal member and the mounting member, the axes on which the two pairs of flexural spring pivot means are aligned being perpendicular, and each flexural spring pivot means of at least one pair thereof including a pair of spring strips having the edges thereof engaging the connected members; and clamping elements overlying said edges and having portions extending beyond the spring strips, said clamping elements being secured directly to the associated members over such portions, said clamping elements, edges and members being welded together.

8. A method of making a gyro rotor assembly which includes an outer member; a gimbal member; a mounting member; the outer member surrounding the gimbal and mounting members; a first pair of aligned flexural spring pivot means connecting the outer and gimbal members; and a second pair of aligned flexural spring pivot means connecting the gimbal and mounting members respectively, the axes on which the pairs of flexural spring pivot means are aligned being perpendicular, the method comprising the steps of forming slots in a single piece of material at positions relatively spaced to correspond to the desired relative spacing of the flexural spring pivot means; forming each flexural spring pivot means by making a symmetrical taper on both sides of the slot; welding clamping elements to selected tapered faces so that each of said clamping elements has a portion overlying its associated tapered face; removing material from the clamping elements to align the edges thereof with the associated edges of the tapered faces; sandwiching a first spring strip between an overlying clamping element and a tapered face on one side of the slot on a first side of the assembly and an overlying second clamping element and the tapered face on the other side of the slot at a second side of the assembly; sandwiching a second spring strip between a third overlying clamping element and the tapered face on the other side of the slot on a first side of the assembly and a fourth overlying clamping element and the tapered face on the one side of the slot on a second side of the assembly; welding spring strips constituting the flexural spring pivot means to the associated members across the slots; and extending the slots so that the outer, gimbal and mounting members are conected only by the spring pivot means.

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