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3,092,424

SELF-COMPENSATED FLEXURE PIVOT

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2 Sheets-Sheet 1

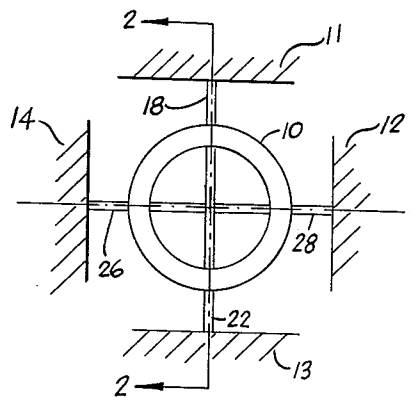


Fig. 1

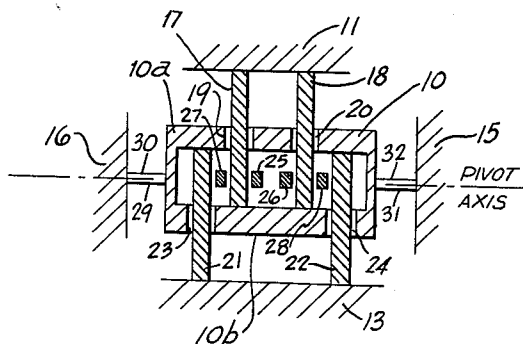


Fig. 2

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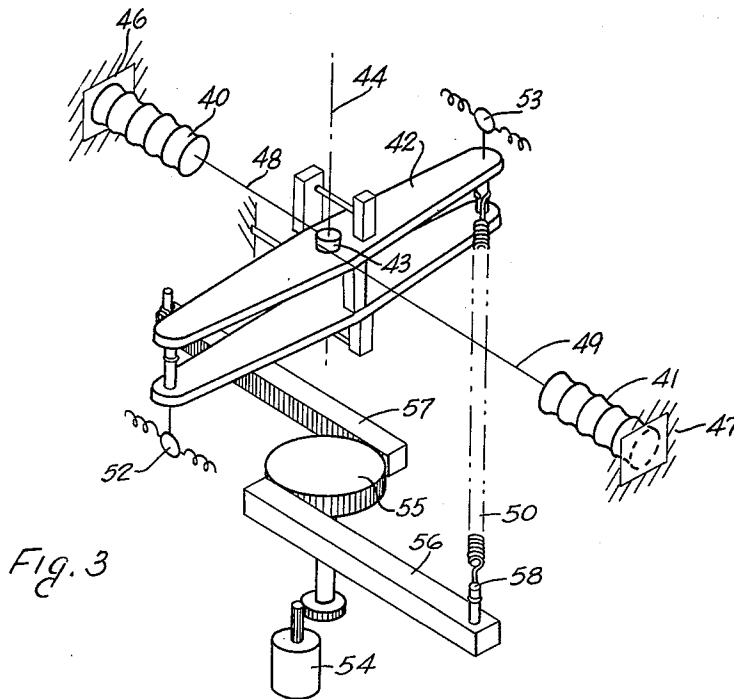
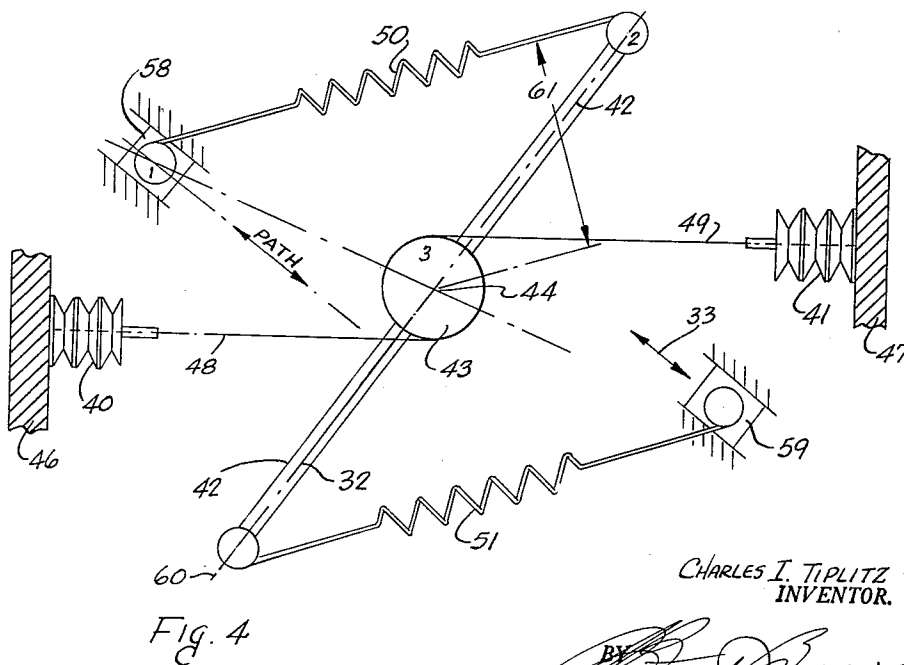
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2 Sheets-Sheet 2



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SELF-COMPENSATED FLEXURE PIVOT

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3 Claims. (Cl. 308—2)

This invention relates to improvements in mechanical pivots and more specifically relates to a self-compensated flexure pivot which is independent of load influence in any direction.

Compensated flexure pivots are well known to the art and are basically comprised of a strip or strips of material supporting the load of a device to be pivoted. The elastic resistance to bending of the strip constitutes the pivot resistance. By properly matching the load to the restoring force of the strip so that the strip is unflexed by the load, the resistance to bending or restoring moment, and thus the pivot resistance can be made substantially equal to zero; that is, the load may be pivoted slightly from its neutral position without resistance due to flexure of the strip. Accordingly, the pivot has the low friction of a knife-edge pivot with the rigidity of a ball bearing.

In the self-compensated flexure pivot, the above concept is followed, but the restoring moment of the pivot is kept at substantially zero under different load conditions. In this device, two parallel pairs of elastic strips are used, one pair arranged to be placed in tension by the load, and the other pair arranged to be placed in compression by the load. If the load on the pivot is now changed, the restoring moment of one of the pairs is increased, while the restoring moment of the other of the pairs is decreased to maintain the net restoring moment equal for any change of load. Accordingly, the pivot resistance remains at substantially zero, even under the new load condition.

The above self-compensating operation follows only when the load is parallel to the length of the pairs of elastic strips. Load increase in another direction will increase the tension in both pairs of elastic strips to upset the balanced condition between the load and the net restoring moment. It has been found that the influence of load changes in a direction perpendicular to the elastic strips and to the pivot axis can be compensated by duplicating pairs of elastic strips in this direction. In this manner, the pivot is self-compensated for all loads acting in a direction perpendicular to the pivot axis. However, there is no compensation for load change in a direction parallel to the pivot axis. Thus, the flexure pivot is not self-compensated for load change in any arbitrary direction.

The principle of the present invention is to fix fine wires under tension from the pivot member to its support in an axial direction and perpendicular to the flexure strips whereby a load change in the direction of the wires does not produce a strain on the flexure strips. Accordingly, in the self-compensated flexure pivot described above having two perpendicular sets of self-compensated pivots, the pivot can be made independent of omnidirectional load by attaching fine wires from the pivot to the pivot frame in a direction perpendicular to the planes containing the perpendicular flexure strips.

Accordingly, a primary object of this invention is to provide a novel means for directionally compensating a self-compensating flexure pivot.

Another object of this invention is to provide a novel pivot which is independent of load change in any direction.

A further object of this invention is to provide a novel pivot having a substantially zero pivot resistance regardless of the direction and magnitude of the load.

A still further object of this invention is to render a

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self-compensated flexure pivot, which is self-compensated for load change in one plane, insensitive to load changes in a direction perpendicular to this plane.

Although the novel pivot of the invention is useful in any appropriate application, it has particular application in an astatic balance which may be used, for example, in a highly sensitive transducer. An astatic balance of this type is shown in copending application Serial No. 855,897, filed November 27, 1959, now U.S. Patent No. 3,054,294 simultaneously herewith, entitled Astatic Balance in the name of John J. Kishel and Charles I. Tiplitz, and assigned to the assignee of the present invention. The application of astatic balances are subject to omnidirectional support. However, an astatic balance may now be economically used in such high sensitivity application as pressure transducers for altimeters and the like by means of the above described novel self-compensated pivot which is independent of omnidirectional load changes.

Accordingly, a further object of this invention is to provide a pivot for an astatic balance.

A further object of this invention is to provide a substantially zero resistance pivot for an astatic balance subjected to omnidirectional load changes.

These and other objects of the invention will become apparent from the following description when taken in connection with the drawings, in which:

FIGURE 1 shows a top sectional view of a self-compensated pivot of the type to which the invention is directed.

FIGURE 2 is a cross-sectional view of the pivot of FIGURE 1 taken across the lines 2—2 of FIGURE 1.

FIGURE 3 is a schematic perspective view showing the application of the self-compensated pivot of the invention to a transducer of the astatic torque balance type.

FIGURE 4 shows a top plan view of the transducer of FIGURE 3 and illustrates the operation of the transducer.

Referring now to FIGURES 1 and 2, an elongated cylinder pivot member 10 is mounted from frame walls 11, 12, 13, 14, 15 and 16. Thus, a first pair of flexure strips 17 and 18 is connected to wall 11, passes through apertures 19 and 20 respectively in pivot member 10 and terminates by connection to the lower inner surface of pivot member 10 as shown in FIGURE 2. A second pair of flexure strips 21 and 22 is connected to wall 13, passes through apertures 23 and 24 through wall 10b of pivot member 10 and terminates by connection to upper inner surface of wall 10a of pivot member 10 as shown in FIGURE 2.

The support for pivot member 10, thus, described, forms a self-compensated flexure pivot for pivot loading in the direction of flexure strips 17, 18, 21 and 22. That is, for any pivot loading in this direction, one pair will be in compression and the other pair will be in tension and the load will be matched to the stress on the flexure strips, so there is no resistance to rotation from the pivot 10. When the loading is changed, the net change in the restoring moment of each of the two pairs of flexure strips will be equal, so that the pivot member 10 can be initially rotated without any substantial opposing force.

In order to self-compensate the pivot for loading in a first direction perpendicular to flexure strips 17, 18, 21 and 22, two other pairs of flexure strips 25—26 carried from side wall 14 and 27—28 carried from side wall 12 are connected to pivot member 10 in the same manner as illustrated for flexure strips, 17, 18, 21 and 22. Accordingly, the flexure pivot will be self-compensated for load changes in any direction in the plane of the drawing of FIGURE 1 and in a vertical plane perpendicular to the drawing of FIGURE 2.

However, the pivot will be affected by load changes in

a plane perpendicular to this compensated plane. In accordance with the invention, the axis of the pivot is connected to the frame carrying the pivot by a fine wire under tension so that load changes in this direction will not apply a stress to the flexure strips. By making the wire fine, or by using a pair of spaced wires, the pivot resistance introduced by these wires can be made negligible and, if desired, their presence can be compensated for in the design of the flexure strips.

The stress preventing wire of the invention is shown in FIGURE 2, as comprising a first pair of wires 29 and 30 which are spaced equidistant from the axis of rotation of pivot member 10 and extend from wall 16 to the left-hand side wall of pivot 10 and a second pair of wires 31 and 32 which are similar to wires 29 and 30 and extend from wall 15 to the right-hand side wall of pivot 10. Accordingly, the pivot member 10 is now compensated for an omnidirectional load change with the tensioned wires 29, 30, 31 and 32 preventing axial load changes from affecting the stressed condition of flexure strips 17, 18, 21, 22, 25, 26, 27 or 28.

A preferred application of the invention is in an astatic type of balance employed as an altimeter or the like. This type of structure is generally shown in FIGURE 3, where a pair of expandable bellows members 40 and 41 are employed to accurately detect the ambient pressure and hence the altitude of the craft upon which the mechanism is carried. Each of the bellows 40 and 41 is disposed on opposite sides of a symmetrical beam member 42 that is pivotally supported at 43 for limited pivoting movement about an axis 44. One end of each bellows is affixed to a frame or housing 46 and 47, respectively, and the other end thereof is connected by means of a tension wire or the like 48 and 49 to the beam 42 on opposite sides of its pivot 43. Consequently, whenever the bellows 40 and 41 experience a change in pressure and in response thereto seek to expand or contract, they exert a torque upon the beam 42 tending to rotate the beam about its axis 44.

To restrain the beam 42 and prevent any appreciable pivoting thereof, there is provided a pair of torque balancing tension springs 50 and 51 connected near opposite ends of the beam 42 and on opposite ends of the beam 42 and on opposite sides thereof, as best shown in FIGURE 4, thereby to exert a counter-balancing torque upon the beam 42 that is equal and opposite to the torque being exerted by the bellows 40 and 41. Consequently, when the device is in equilibrium, the torque exerted by the bellows 40 and 41 is balanced by the opposing torque produced by the springs 50 and 51 and the beam remains stationary about its pivot axis 44. Additionally, the translational force exerted against the beam 42 by the bellows 40 is substantially equal and opposite to that exerted by bellows 41, and the translational force exerted by spring 50 is likewise substantially equal and opposite to that of spring 51. Consequently, since the forces of each pair are equal and oppose one another in direction, it is also evident that the beam 42 is free of net translational forces there-against, and its pivot 43 experiences substantially no translational force tending to disturb its orientation or causing excessive stress.

With the arrangement of elements as thus far described, it is believed evident that expansion or contraction of the bellows 40 and 41, in response to changes in outside pressure, would exert an increased or decreased turning torque upon beam 42 thereby pivoting the beam 42 about the axis 44 and allowing the bellows 40 and 41 to expand or contract normally. However, presently available bellows devices suffer from the disadvantage of providing rather large hysteresis errors wherein the bellows devices do not identically duplicate their former position when exposed to the same pressures but rather assume a different expanded or contracted position and hence introduce an error in the pivotal displacement of the beam 42. Therefore, to prevent expansion or con-

traction of the bellows, there is provided a force balancing system that substantially prevents the bellows devices 40 and 41 from changing dimension, and instead permits variation of only the forces that these devices exert on the beam 42 by providing a follow-up balancing system to always maintain the beam 42 substantially in its original position.

Referring to FIGURE 3 for an understanding of the force follow-up device, there is provided at each end of the beam 42, a pickoff device 52 and 53, respectively, that accurately detects even the slightest displacement of the beam 42 about its pivot 43 to produce an electrical signal. This displacement signal is directed to energize a follow-up motor 54, which through suitable gearing, such as a pinion 55 and racks 56 and 57, positions the opposite ends of each restoring spring 50 and 51 in a transverse direction toward and away from the pivoted beam 42.

More specifically, the end of spring 50 opposite that attached to the beam 42, is connected at position 58 to one end of the rack 56 and the end of spring 51 opposite that attached to the beam, is likewise connected to one end of rack 57 at a position 59, and both racks 56 and 57 are engaged by pinion gear 55 to move in opposite directions with rotation of the pinion gear 55. Consequently, upon being energized by the error signal from pickoffs 52 and 53, the drive motor 54 rotates the pinion gear 55, which, in turn, positions the racks 56 and 57 in opposite directions and transverse to the beam 42 and in doing so, simultaneously positions the ends of spring 50 and 51 toward and away from the beam 42 along paths perpendicular to the beam, as best shown in FIG. 4.

As illustrated in FIGURE 4, this movement of the ends of springs 50 and 51 toward and away from beam 42 varies the moment arm provided by the spring restoring forces against the beam, whereby as the spring ends 58 and 59 are positioned transversely away from the beam, the moment arm is increased and as the spring ends 58 and 59 are positioned toward the beam 42, the spring moment arms are simultaneously decreased. In this manner the spring balancing torque provided by springs 50 and 51 may be automatically varied in a follow-up arrangement to counter-balance the torque exerted by the bellows device 40 and 41 and thereby maintain the stabilized beam 42 in its neutral position.

If spring ends 58 and 59 are momentarily fixed, the restoring springs 50 and 51 will expand or contract as beam 42 moves clockwise or counter-clockwise in FIGURE 4. At the same time, moment arm 61 in FIGURE 4 will decrease or increase correspondingly. Furthermore, the torque exerted by the bellows will decrease or increase respectively for this motion of beam 42. It has been found, and may be mathematically demonstrated that for a clockwise rotation of beam 42, the decrease in moment arm 61 will exactly compensate for the increase in the difference between the increasing force of springs 50 and 51 and the decreasing force exerted by the bellows 40 and 41 on beam 42 only if the path of the spring ends 58 and 59 is exactly perpendicular to the axis 60 of beam 42. Also, if beam 42 rotates counter-clockwise, the increase in moment arm 61 will exactly compensate the decrease in the difference between the spring and bellows forces on beam 42 if the spring ends 58 and 59 move perpendicular to axis 60.

More specifically, if the spring ends 58 and 59 are momentarily fixed and if the path of the spring ends is restricted to move perpendicularly to axis 60 of beam 42, then it is possible to design the springs so that there is no resistance to clockwise or counterclockwise rotation of beam 42 about axis 44 due to the elastic properties of springs or bellows. Consequently, for the condition that axis 62 and axis 63 be perpendicular to axis 60, with proper springs, beam 42 will turn through a large angle about axis 44 for any pressure change between the in-

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side and outside of bellows 40 and 41, no matter how small the change.

It is to be noted that a damping means (not shown) is attached to the system to prevent hunting. Therefore, extremely small pressure changes will be detected by pickoffs 52 and 53 which will energize drive motor 54 until equilibrium is restored.

The above operation will be recognized as an astatic operation, and it will also be recognized that the pivot resistance should be as low as possible if the high sensitivity advantages of the astatic balance are to be retained. For this purpose, the novel compensated pivot 10 of FIGURES 1 and 2 may be used as pivot 43 in FIGURES 3 and 4. Therefore, regardless of changes in pivot loading, as due to acceleration in any direction, the pivot resistance will remain substantially zero.

By using this novel pivot, it has been found that the pivot resistance is approximately 2.0 dyne centimeters/degree of pivot rotation. Therefore, it is possible to use an astatic type of instrument of the type shown in FIGURES 3 and 4 where the altimeter sensitivity was 3 ft./100,000 ft. when tension wires such as wires 29, 30, 31 and 32, are used. Because of the nature of the astatic balance, this sensitivity is uniform over a great altitude. In the absence of wires 29, 30, 31 and 32, the flexure strips must be designed to withstand perpendicular load changes and the sensitivity of the instrument was reduced from 3 ft. at 100,000 ft. to 50 ft. at 100,000 ft.

Since the above and many other modifications are considered within the skill of those versed in the art after a detailed consideration of the foregoing specification, this invention is to be limited only by the following claims;

What is claimed is:

1. A self compensated flexure pivot, comprising in combination,
 - a an elongated cylinder including inner and outer wall portions and end members extending at least across the cylinder diameter, said pivot being designed to be supported by first, second, third, fourth, fifth and sixth supports disposed about the pivot at right angles to each other;
 - a first elongated flexure means, extending from said first support through said cylinder outer and inner wall portions at one side across the center of the cylindrical axis over to the inner wall portion at the other side;

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a pair of second elongated flexure members of equal length extending from said second support through said cylinder outer and inner wall portions across the cylindrical axis over to the inner wall portion at the other side, but displaced circumferentially from said first support by 90° and passing on the one and the other side of said first flexure means at equal distances therefrom;

a pair of third elongated flexure members of equal length extending from said third support through said cylinder outer and inner wall portions across the cylindrical axis over to the inner wall portion at the other side parallel to said first elongated flexure means but displaced circumferentially therefrom by 180°, passing on the one and the other side of said first elongated flexure means at equal axial distances from said first flexure means.

a pair of fourth elongated flexure members of equal length extending from said fourth support through said cylinder outer and inner wall portions across the cylindrical axis over to the inner wall portion on the other side, parallel to said pair of second elongated flexure members but displaced circumferentially therefrom by 180°, passing on the one and the other outer side of said first elongated flexure means at equal axial distances from said first means; and,

tensioned wires of equal length, extending from said fifth and sixth supports to that portion of opposite end members at the axis of the cylinder.

2. A device as claimed in claim 1, wherein said third members are disposed axially outwards of said second members and said fourth members are disposed axially outwards of said third members.

3. A device as claimed in claim 2 wherein said first elongated flexure means has two parallel elements each disposed equidistant from the axial center of said cylinder.

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