Sept. 23, 1969 J. L. EVANS 3,468,170

APPARATUS FOR REDUCING GAS COUPLING BETWEEN THE STATOR AND ROTOR OF GYROSCOPES

Filed Dec. 29, 1966 2 Sheets-Sheet 1

Fig. 1.

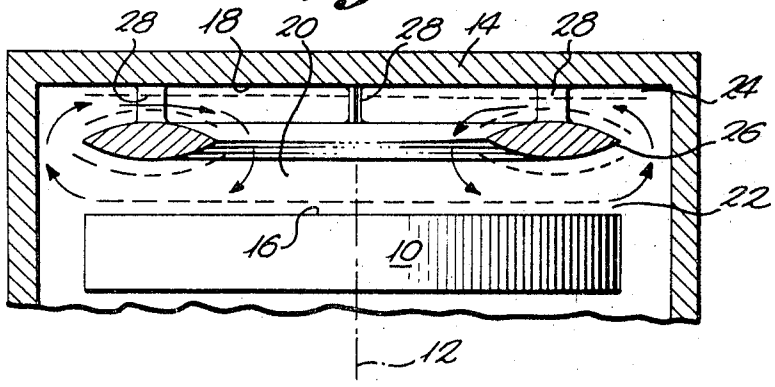
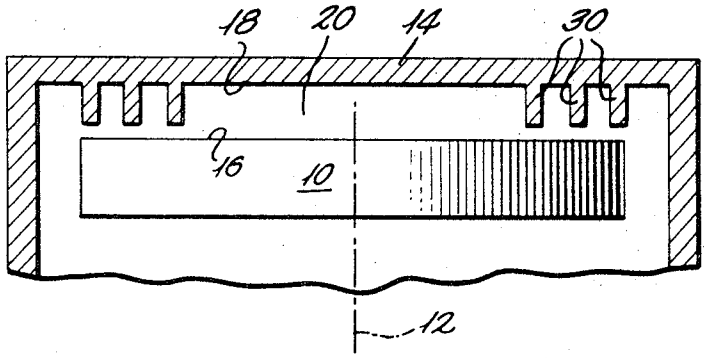


Fig. 2.



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Fig. 3.

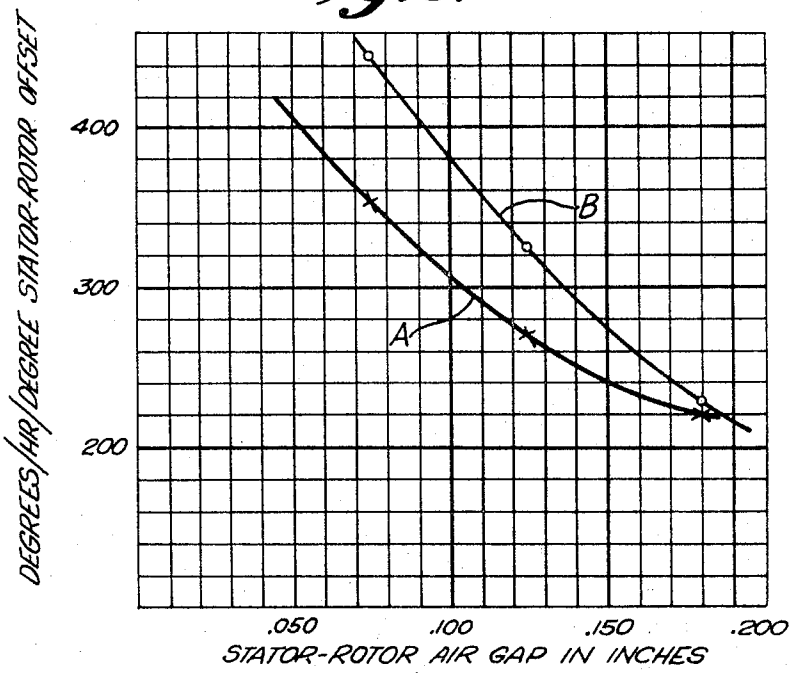
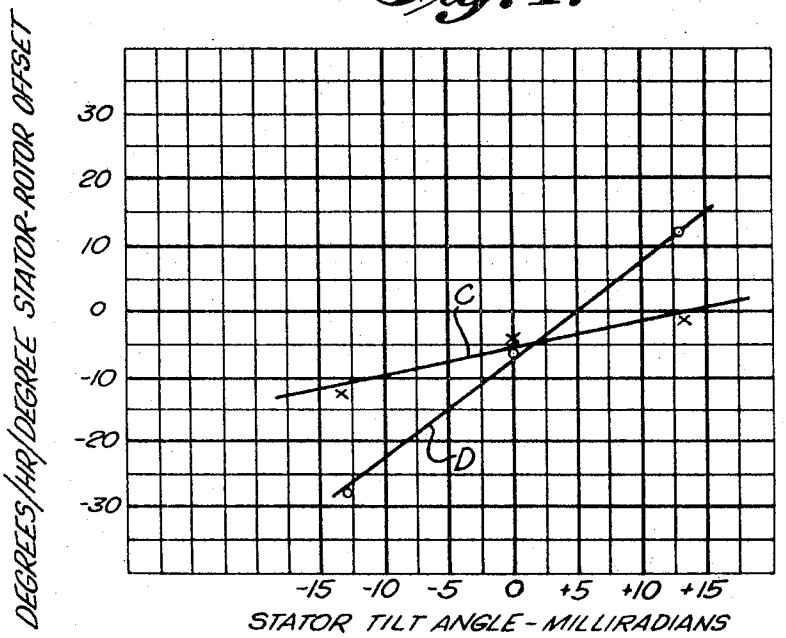


Fig. 4.



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APPARATUS FOR REDUCING GAS COUPLING BETWEEN THE STATOR AND ROTOR OF GYROSCOPES

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U.S. Cl. 74—5 5 Claims

ABSTRACT OF THE DISCLOSURE

This disclosure includes drawings and a description of two forms of apparatus for reducing the gas coupling restraint between the rotor and stator of a free rotor gyroscope by minimizing pressure buildup near the outer edge of the rotor that ordinarily occurs because of the centrifugal pumping effect of the rotor. In one embodiment, the pressure buildup is reduced by an annular flow divider in the stator-rotor gap to effect uniform radial circulation of gas or air in the gap. In the other embodiment, annular baffles are mounted on the stator to project into the gap to inhibit outward movement of gas. The drawing also includes graphs showing performance curves for the respective embodiments.

BACKGROUND OF THE INVENTION

This invention relates to gyroscopes, and more particularly, it concerns an arrangement for reducing adverse gas coupling effects that occur between the stator and rotor of a gyroscope due to static pressure distribution developed by centrifugal pumping action of the rotor in operation.

In the operation of free rotor gyroscopes, a gas coupling is developed between the rotor and the stator or case of the gyroscope which tends to cause the rotor to be moved with the case as the latter moves in space with the vehicle or other device on which it is carried. This tendency for the rotor to follow case movement is undesirable in that the usefulness of the rotor as a directional reference is impaired. Two different phenomena are believed to be the cause of the gas coupling referred to. The first of these phenomenon is viscously controlled self-acting gas bearing effects which are generally independent of ambient gas density. Because of available analyses of the behavior of these self-acting gas bearing effects, they can be reduced to acceptable values by studying and applying equations that predict their behavior. The second of the two different phenomena referred to is dependent on ambient gas density and results from the centrifugal pumping effect of the spinning rotor. The pumping effect causes a static gas pressure distribution to exist between spaced mutually facing surfaces of the rotor and the stator or case, particularly toward the outer edge of the rotor. This pressure distribution becomes non-uniform, causing rotor drift, whenever symmetry about the rotor spin axis is disturbed.

SUMMARY OF INVENTION

In accordance with the present invention, the undesirable gas coupling between a gyroscope rotor and stator is reduced significantly by minimizing pressure buildup as a result of the centrifugal pumping action of the rotor. In one embodiment, the pressure buildup or distribution toward the outer edge of the rotor is avoided by placing an annular flow divider in the clearance gap between the mutually facing surfaces of the rotor and stator so that the outward flow of gas resulting from the centrifugal pumping effect of the rotor is accompanied

by a substantially equal inward flow of gas between the flow divider and the stator. In other words, the arrangement referred to establishes a circulatory path for gas so that a substantially uniform pressure exists between the radial face and the stator. In another embodiment the undesirable static pressure distribution toward the outer edge of the rotor is avoided by an annular baffle arrangement which inhibits the flow of gas due to the centrifugal pumping effect of the rotor.

A principal object of the present invention is, therefore, to provide means for reducing the gas coupling that develops between a gyroscope stator and rotor as a result of the centrifugal pumping effect of the spinning rotor.

Another object of the present invention is the reduction of the gas coupling between the gyroscope rotor and stator that tends to cause drift of the rotor spin axis upon relative movement between the stator and the rotor.

Still another object of this invention is the provision of a gyroscope with means by which the static gas pressure between the radial end faces of the rotor and the casing is maintained substantially uniform over the radial end face of the rotor.

A further object of this invention is the provision of a gyroscope having means for preventing static gas pressure distribution as a result of the centrifugal pumping effect of the spinning rotor.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description of the preferred embodiments given below, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing, like reference numerals designate like parts and:

FIG. 1 is a fragmentary elevation schematically illustrating the rotor and stator of a gyroscope together with the one form of the device for reducing the gas coupling between the rotor and the stator;

FIG. 2 is a similar view illustrating an alternative form of the present invention;

FIG. 3 is a graph illustrating performance curves of the embodiment of FIG. 1; and,

FIG. 4 is a graph showing comparative performance curves of the embodiment of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1 of the drawings, is will be noted that a gyroscope assembly is schematically depicted and includes a rotor **10** rotatable on a spin axis **12** in a stationary casing or stator **14**. The rotor is supported in the casing by conventional means (not shown) such as gimbals, fluid or gas bearings, and the like. The rotor, which may assume many shapes and forms other than the simplified cylindrical form shown in FIG. 1, will have an end face **16** in a conventional gyroscope which is spaced from a mutually facing end face **18** in the stator **14** to establish a clearance gap **20**.

When the gyroscope is in operation, the rotor **10** is rotated at high speeds about the spin axis creating a centrifugal pumping effect which causes gas or air in the gap **20** to flow outwardly from the spin axis on the side of the gap closest to the rotor end face **16**. More specifically, the circulatory path or pattern of gas flow in the gap **20** includes boundary film **22** adjacent to and movable with the surface of the rotor and a similar relatively static boundary film **24** adjacent the end face of the stator **14**. As aforementioned, the flow of gas between the boundary films and near the end face **16** of the rotor will be outwardly, tending to create a high static pressure distribution about the outer edge of the rotor. In conven-

tional gyroscopes heretofore available, no means has been provided to reduce this pressure buildup near the edge of the rotor. As a result, whenever the stator is tilted with respect to the spin axis, the pressure distribution referred to becomes uneven relative to the spin axis. This uneven pressure distribution acts like a spring restraint on the rotor tending to shift it in a direction to follow the stator.

In accordance with the present invention, and particularly in accordance with the embodiment of FIG. 1, pressure buildup near the outer edge of the rotor is reduced significantly by placing an annular flow divider or ring **26** in the gap **20** between the end faces **16** and **18** on the rotor and stator, respectively. The ring may be supported from the stator by four struts **28** which are sufficiently small in size so as not to affect the flow of air about the flow dividing ring **6**. Because of the ring **26** and its generally oblong radial cross section, the outward flow of air between the rotor and the ring in no way impairs the return flow of gas between the ring and the stator. As a result, a more uniform circulation of gas outwardly in the vicinity of the rotor and inwardly in the vicinity of the stator occurs with minimal pressure buildup near the outer edge of the rotor.

The performance curve of FIG. 3 illustrate the improved results achieved with the flow divider **26** as compared with the same gyroscopes without the flow divider. In FIG. 3, gas coupling spring restraint in degrees per hour of rotor drift per degree of offset between the rotor and stator (degrees/hour/degree stator-rotor offset) are plotted against the rotor-stator gap (the air gap **20**). Where these functions were plotted with a gyroscope having the flow divider ring **26** curve A resulted. Curve B was plotted with a gyroscope without the flow divider. It is apparent that the spring restraint or gas coupling values in curve A are significantly lower than in curve B for a corresponding width of the air gap **20**. As the clearance or air gap increases in width, the advantage of the flow divider ring **26** diminishes since the net effect of the stator is reduced. It will be appreciated, therefore, that the embodiment of FIG. 1 is particularly suitable for gyroscopes where the boundary layers **22** and **24** are small as compared with the rotor-stator gap **20**. In other words, the flow divider ring **26** is useful for where the gap **20** is between approximately 0.050 inch and 0.175 inch. Where the gap is less than 0.050 inch, the problems of mounting the ring **26** in the gap offset the advantages derived therefrom.

The embodiment of FIG. 2 is particularly suitable for use in gyroscopes where the clearance gap **20** is small or generally less than 0.080 inch. In this instance, a series of annular rings or flutes **30** project from the stator end face **18** into the gap toward the rotor **10**. The specific dimensions of the rings in the embodiment of FIG. 2 where the clearance gap is 0.080 inch wide is 0.025 inch in radial thickness and 0.062 inch in an axial direction. Also, the spacing between the rings **30** is approximately 0.075 inch in this arrangement. Because the rings **30** extend over 75 percent of the width of the gap **20**, the efficiency of the rotor as a centrifugal pump is significantly impaired. This impairment of the centrifugal pumping effect of the rotor prevent the pressure distribution referred to above with respect to the embodiment of FIG. 1. Also, because the rings project over a very small cross sectional area of the rotor, neither circumferential flow, leakage or rotor drag are significantly affected.

Two types of tests have been performed with and without the ring **30** in the embodiment of FIG. 2. In the first of these tests, the quadrature restraints acting on the rotor as a result of tilting the stator through 10 minute steps were measured with and without the rings in place. The results of this test with the rings **30** were restraints resulting in rotor drift of approximately 128 degrees per hour per degree of offset between the rotor and stator. Without the ring **30**, about 82 degrees of rotor drift occurred for each degree of offset between the rotor and stator.

In a second test, the stator **14** was tilted through a known angle and the initial drift rate of the rotor observed. FIG. 2 shows a summary of these measurements in the form of two generally straight-line curves C and D where rotor drift in degrees per hour per degree of offset between the rotor and stator are plotted against the cover tilt angle in miliradians. Curve C represents the performance of test results with the rings **30** in place and with a cover rotor gap or clearance of 0.10 inch. Curve D represents a flat cover, or one without the rings 30, with a gap of 0.65 inch. Despite the relatively small gap in the test performed with the rings **30**, significantly less gas bearing spring effect was experienced with the rings **30**.

Thus it will be apparent that by this invention, an improved means is provided for reducing the stator-rotor gas coupling effects in a gyroscope and by which the above objectives are completely fulfilled. It will be appreciated that the various modifications in the present invention may be made other than those described and illustrated herein and without departing from the spirit of this invention. Accordingly, it is expressly intended that the foregoing description is illustrative of preferred embodiments only, not limiting, and that the true spirit and scope of the present invention is to be determined by reference to the appended claims.

I claim:

1. A gyroscope comprising:

a stator,

a rotor having a spin axis, said rotor and stator having mutually facing spaced surfaces defining a clearance gap extending in a generally radial direction relative to said spin axis, and

means to cancel pressure buildup of gas in said gap that occurs due to the centrifugal pumping effect of said rotor when the latter is moved relative to said spin axis whereby the tendency for said rotor to drift with said stator is reduced, said means comprising an annular flow-dividing member positioned about said spin axis in said clearance gap and having a tapered oblong configuration in radial cross section.

2. The apparatus recited in claim **1** including struts to support said annular member from said stator.

3. A gyroscope comprising:

a stator,

a rotor having a spin axis, said rotor and stator having mutually facing spaced surfaces defining a clearance gap extending in a generally radial direction relative to said spin axis, and

means to cancel pressure buildup of gas in said gap that occurs due to the centrifugal pumping effect of said rotor when said stator is moved relative to said spin axis, whereby the tendency for said rotor to drift with said stator is reduced, said pressure cancelling means comprising baffle means to impair outward flow of gas in said gap due to the centrifugal pumping effect of said rotor wherein said baffle means comprises a plurality of annular rings supported on said stator and projecting into said clearance gap toward said rotor.

4. The apparatus recited in claim **3** in which said rings extend at least 75 percent of the width of said clearance gap.

5. The apparatus recited in claim **4** in which the radial thickness of said rings is small relative to the axial distance they project in to said clearance gap.

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