United States Patent [19]

Lynch et al.

[11] **3,716,206**

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[54] **NUTATION DAMPER**

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[73] Assignee: **RCA Corporation**

[22] Filed: **Nov. 16, 1970**

[21] Appl. No.: **89,936**

[52] **U.S. Cl.**.....**244/1 SA**, 74/5.5, 74/574

[51] **Int. Cl.**.....**B64g 1/10**

[58] **Field of Search**.....244/1 SA, 1 SS; 74/574, 573, 74/5.5, 5.8; 188/266, 269, 290

[56] **References Cited**

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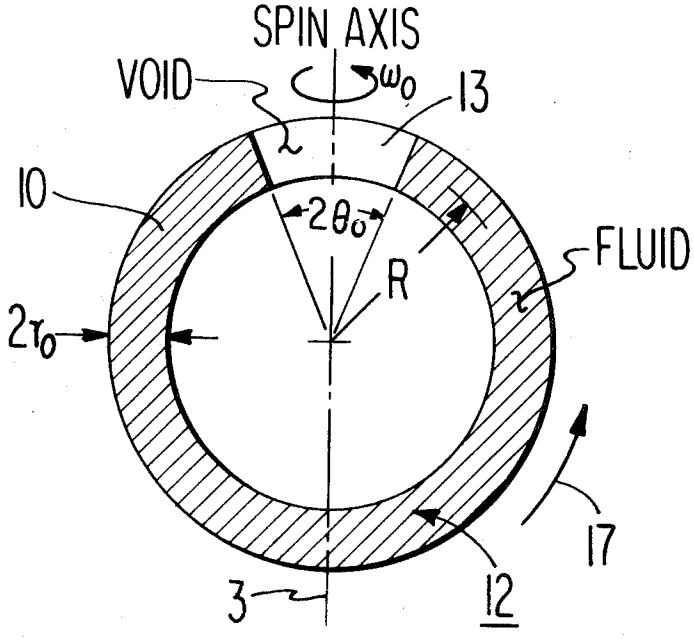
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[57] **ABSTRACT**

A damper in the form of a generally ring-like container of viscous fluid filling a substantial portion of the container the remaining portion of which defining a void or bubble. The container is spun by being oriented within a spinning portion of a spacecraft or is provided with means to spin relative to the stable body portion of a spacecraft. Centrifugal forces on the fluid in the presence of nutational motions will develop oscillations of the bubble relative to the spinning axis of the container to generate energy losses thereby reducing nutation motion. Fluid resonance is developed with bubbles of selected size in ring-like containers. Resonance is also developed in a U-shape configuration having different sized cross-sectional portions.

14 Claims, 10 Drawing Figures



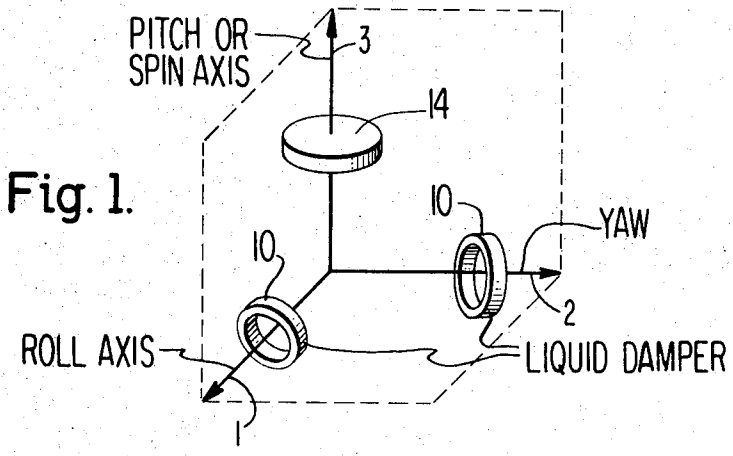


Fig. 1.

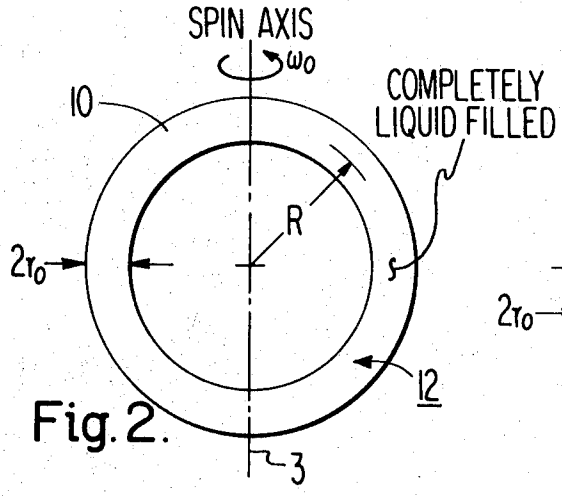


Fig. 2.

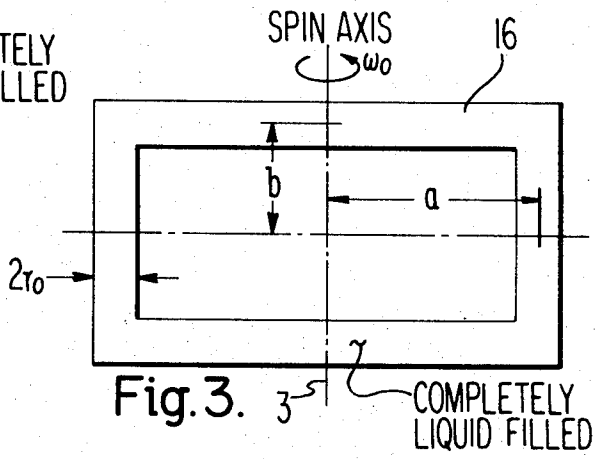


Fig. 3.

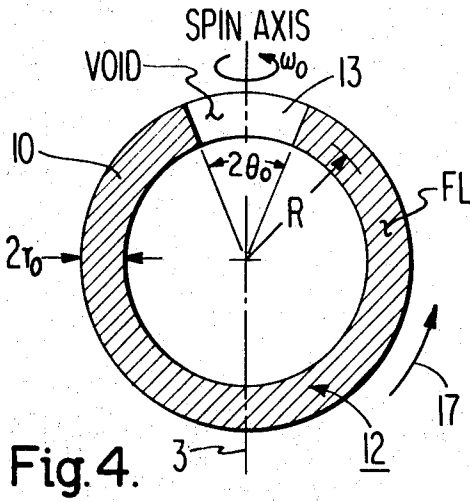


Fig. 4.

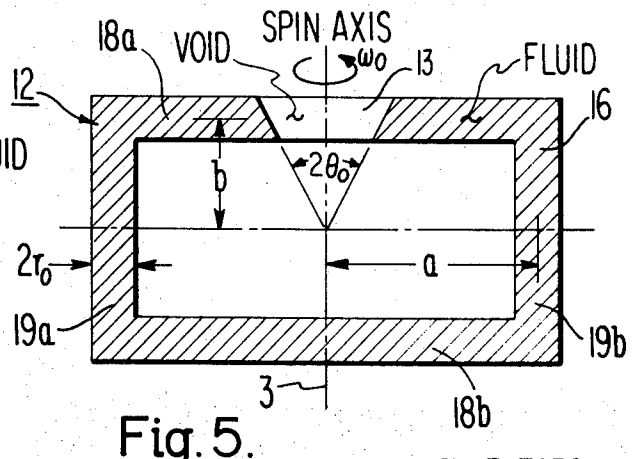


Fig. 5.

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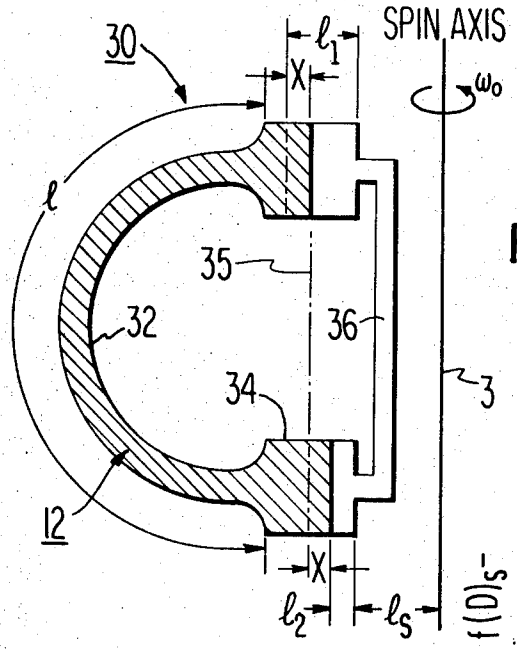


Fig. 6.

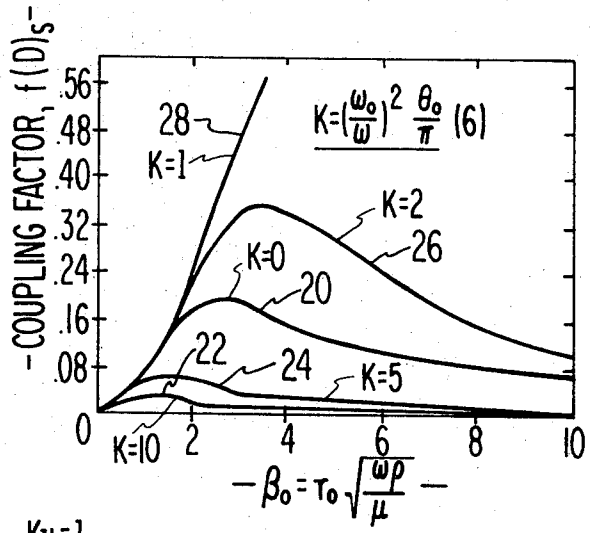


Fig. 7.

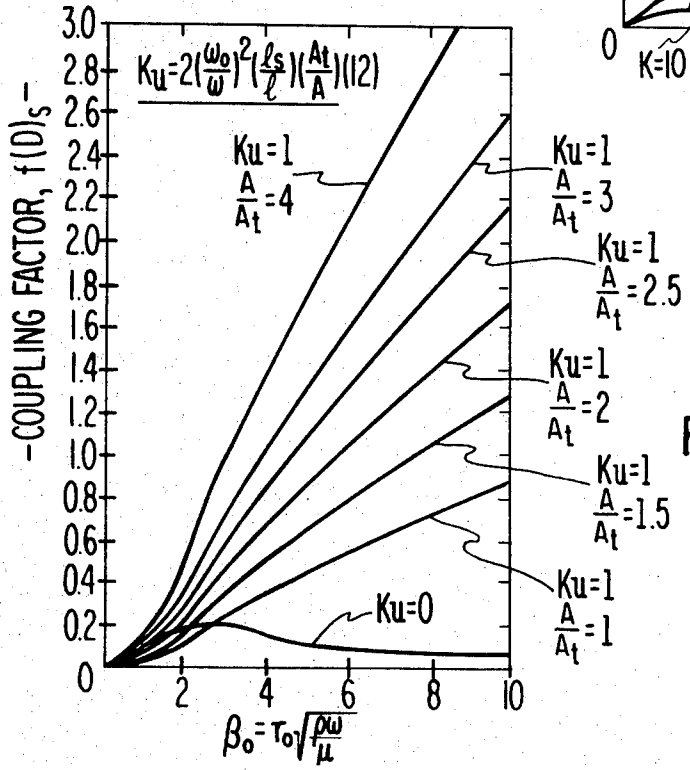


Fig. 8.

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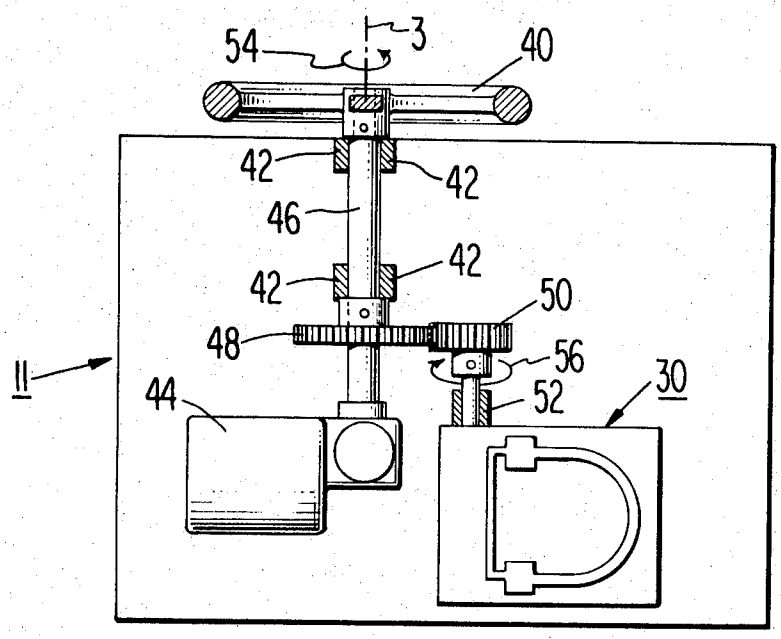


Fig. 9.

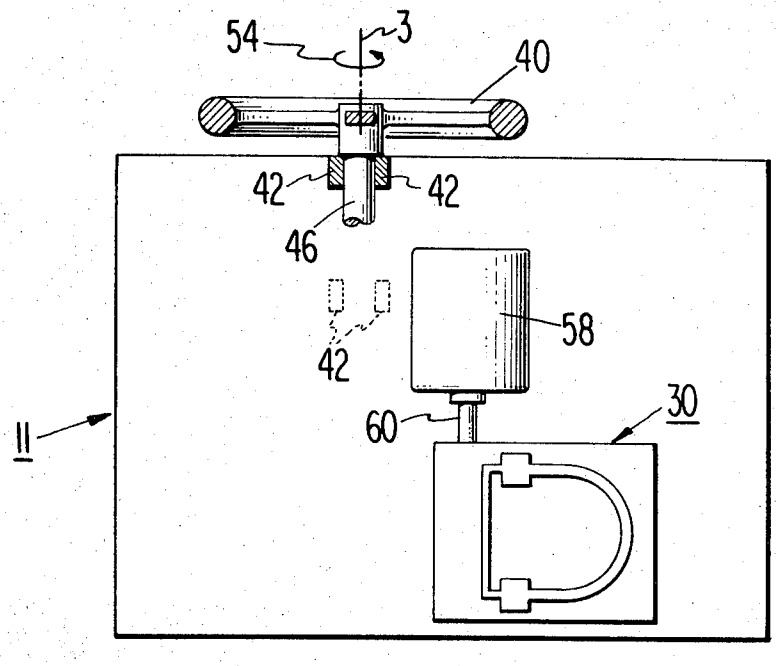


Fig. 10.

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NUTATION DAMPER

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to attitude controlling of space satellites, and more particularly to a device for providing passive damping of nutation motions.

2. Description of the Prior Art

The gyroscopic effect of a spinning body is used to assist in establishing a stable attitude for a space satellite so that, among other things, a given body axis may be directed or pointed to a desired reference such as a star, the sun or the earth. The entire body of certain spacecraft are arranged to spin about a central axis to develop the desired gyroscopic action. In certain other types of spacecraft a momentum wheel spinning about a central axis by means of a motor coupled from a stable or non-rotating portion of the spacecraft provides an equivalent gyroscopic stabilization effect. Such latter spacecraft are well known being more commonly identified as de-spun spacecraft. The free motion of the spacecraft nevertheless develops a wobble, more accurately, nutation of the spin axis, describing a cone about the total momentum vector of the spacecraft. It should be noted that the frequency of the nutation motion of a spin stabilized spacecraft for a given momentum is a constant determined by the design of the satellite, as well known in the art. Such nutation motion can be attenuated, if not eliminated, by the action of a properly installed energy-absorbing nutation motion damper.

In the present state of the art, various types of devices have been utilized to damp nutation motion among which are the more commonly known viscous dampers. Such devices are generally ring-shaped containers or reservoirs of highly viscous fluid completely filling the container. The plane of the container is oriented in the spacecraft parallel to the spacecraft spin or momentum axis. When the vehicle is nutating or wobbling, the damper is subjected to various accelerations imposed on it by the motion of the spacecraft. Of all of the acceleration forces imposed on the completely contained liquid, only those accelerations along the length of the tube (i.e., the tangential forces) are effective in producing fluid motion, the non-tangential accelerations being balanced by pressure reactions within the fluid. In response to the accelerations forces acting on the damping device, only those portions of the fluid momentum which is in a 90° phase relation with the tube wall portions perpendicular to the spin of the satellite will develop fluid reaction to oppose the nutation motion to thereby attenuate the nutation motion.

In such viscous fluid damping devices, bubbles develop within the fluid owing to contractions in response to low temperatures such as are either experienced by spacecraft flying in outer space and away from the effects of solar heat or by imperfect filling of the fluid in the container. It is known that such bubbles can degrade the damping effect of such dampers. This invention is based on the discovery that a bubble in such dampers can be utilized advantageously to improve the effectiveness thereof. It is desirable and therefore an object of this invention, to provide a nutation damper of the viscous fluid type that will effect nutation damping notwithstanding the presence of bubbles and, indeed, to utilize the bubbles advantageously.

SUMMARY OF THE INVENTION

According to the invention a nutation damper is provided in the form of a generally ring-like hollow tube provided with viscous fluid filling a substantial portion of the tube. A bubble or void is established in the ring situated along the spin axis about which the ring-like member is spun. The fluid is arranged to flow in a plane substantially parallel to the axis of spin by orienting the phase of the tube parallel to the spacecraft spin axis. The size of the bubble relative to the quantity of viscous fluid in the ring improves the viscous coupling factor causing the viscous friction for damping the nutation motion. Fluid resonance can be achieved with a properly related bubble or enlarged expansion portions, whereby a significant figure of improvement of damper effectiveness is obtained.

BRIEF DESCRIPTION OF THE DRAWING

The nature of the invention is hereinafter further explained in greater detail by several illustrative embodiments with reference to the accompanying drawing in which:

FIG. **1** is a diagram showing the spacecraft axes and the relation of the angular momentum vector to the viscous dampers;

FIG. **2** is a schematic of a toroidal form of a damper which is completely filled with viscous fluid;

FIG. **3** is a schematic of a rectangular form of damper completely filled with viscous fluid;

FIG. **4** is a schematic of a toroidal form of damper according to the invention having a void or bubble in a portion thereof;

FIG. **5** is a schematic of a rectangular form of damper according to the invention similarly having a void or bubble;

FIG. **6** is a modified geometrical form of the invention in a U-shaped configuration having an enlarged expansion portion wherein the bubble or void is restricted to a portion of the device;

FIG. **7** is a plot of the viscous coupling factors of a toroidal damper for different size bubbles;

FIG. **8** is a plot of viscous coupling factors of a U-shaped damper for different area ratios each at resonance; and

FIGS. **9** and **10** illustrate two additional embodiments of the invention for use on a non-spinning platform.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing and in particular first to FIG. **2**, there is shown a schematic of a toroidal damper **10** formed preferably of aluminum for adequate strength and relative lightness having a circular cross section with a mean radius R and a cross sectional radius r_0. The inner hollow portion of the toroid **10** is filled with viscous fluid **12** such as silicone oils. The toroid functions as a damper of nutation motion about the spin axis of a spacecraft while it is being spun about the spin (**3**) axis of a satellite with an angular velocity ω_0.

The damper **10** is disposed in a satellite **14** along either or both of the transverse axes **1** and **2** as shown in FIG. **1**. The **1** axis as known in the art may be the roll axis and the **2** axis may be the yaw axis, the spin or

pitch (3) axis being usually coincidentally or parallel with the momentum vector H of the spacecraft.

The satellite **14** as depicted in FIG. **1** is shown in schematic form in relation to the respective body axes **1** (roll), **2** (yaw), and **3** (pitch or spin). It is understood that one or more dampers **10**, for convenience, shown external to the satellite **14**, are usually mounted within the satellite body **14** in a manner well known in the art. The momentum vector H for stabilized operation is preferably coincidental with the spin (**3**) axis. The spinning of the spacecraft is usually initially established during launch and after launch, adjustments of the spin rate are made by suitable control devices such as rockets or magnetic torquing devices (not shown) or combinations of both as known in the art.

The angular momentum of the spacecraft **14** when in line with the momentum vector H produces no net torques caused by viscous drag of the fluid within the toroid dampers affecting the dynamic stability of the spacecraft. Thus as known in the art the system is stable and no damping function is imposed upon the dampers. However, nutation motion excites the toroidal damper tangentially, causing the contained liquid, by virtue of the viscous effect (or drag) of the surrounding walls of the tube, to flow relative to the tube. The energy absorbed by this action is taken from the forces causing or which caused the nutation motion and a portion of that energy is transferred through the spacecraft to the spin (**3**) axis.

In certain environments a toroidal configuration is not suitable and accordingly rectangular configurations **16** as illustrated in FIG. **3** are used. The principle of operation of such a configuration is essentially the same as that as for the toroidal form of damper. Geometrically the rectangular damper is defined by the mean longitudinal length of the viscous fluid containing portion by the long leg dimension a and the short leg dimension b. The rectangular damper **16** is shown spinning about its spin axis corresponding to the **3** axis of FIG. **1**.

A mathematic analysis of the damper will provide the foundation for a better understanding of the invention. The equation for the rotational inertia of the viscous fluid in the toroidal damper **10** is

$$I=\rho 2\pi R\pi r_0^2 R^2 \tag{1}$$

where

ρ is the fluid density;

r_0 and R are the radii as previously defined and indicated in FIG. **2**.

It can be shown that the angular momentum of the fluid, I may be expressed by the following equation:

$$I=TW_{T0}e^{\alpha-jwt} \tag{2}$$

where

I is defined by equation 1 above;

ω_{T0} is the angular velocity of the transverse spin rate, that is, the velocity of either or both of the roll axis and the yaw axis;

α is defined by the equation

$$\alpha = 2J_1(\beta_0)/\beta_0 J_0(\beta_0) \tag{3}$$

where

J is the Bessel function operator; and

β is the conventional argument of the Bessel functions known in the art. The magnitude of the imaginary part of α is the effectiveness or viscous coupling factor for a pair of damper devices **10** as shown in FIG. **1**. This is mathematically shown by equation **4**

$$f_{(D)}=\text{imaginary}\,[\alpha] \tag{4}$$

from which the coupling factor $f_{(D)s}$ is represented by equation

$$f_{(D)s}=f_{(D)}/2 \tag{5}$$

The factor $f_{(D)s}$ is plotted in FIG. **7** as it varies as a function of $\beta_0=r_0(\omega\rho/\mu)^{1/2}$

where

μ is the viscosity;

r_0 is the inner radius of the tube;

ω is nutation frequency;

ρ is specific density of the fluid (μ/ρ = kinematic viscosity).

The abscissa of FIG. **7** is the characteristic number of the damper as defined by the parameters shown. This number is analogous to the Reynold's number.

The graph of FIG. **7** includes the plot of equation 5 for a $K=0$ as indicated by curve **20** where K is defined by the following equation:

$$K=(\omega_0/\omega)(2\theta_0/\pi) \tag{6}$$

where

ω_0 is the damper spin rate along the axis parallel to the spin axis **3**;

ω is the nutation frequency exciting the fluid damper **10**;

θ_0 is the half-angle intercepted by the bubble or void measured from the center of the toroid or rectangle (FIGS. **4** and **5**) as will be described more fully hereinafter.

Curve **20** is a plot of a toroidal damper without a bubble as per FIG. **2** for example. A study of curve **20** shows that a maximum value of the coupling factor $f_{(D)s}$ of about 0.189 is achieved with the abscissa having a value of about 2.5. Thus, with such a curve one can determine the maximum or optimum coupling factor for the radius, velocity, viscosity and the density of the fluid in a toroid without a bubble.

A bubble or void in the viscous fluid contained within the damper affects the coupling factor $f_{(D)s}$ depending upon the size of the bubble. Referring now to FIG. **4** there is shown the toroid damper **10** of FIG. **2** with the fluid **12** only partially filling the damper, the remaining portion being defined by the void or bubble **13**. The portion **13** may be a vacuum or filled with a vapor having low viscosity properties. The angle θ_0 subtends or intercepts one-half of the total angle, the total angle thus being $2\theta_0$. The arrow ω indicates the nutation frequency.

It has been discovered that the size of the bubble, as defined by the angle θ_0, is critically related to the coupling factor effect of a damper without a bubble as a reference. Referring to FIG. **7**, several curves are shown illustrating this criticality.

Curve **20** is for a factor of $K=0$ for which there is no void or bubble. As the bubble size is increased the factor K increases from 0 to 1.0. When $K=1.0$ (curve **28**) the bubble is at the critical size wherein resonance occurs. The coupling factor $f_{(D)s}$ increases very rapidly for increasing values of β_0 according to the resonant curve **28**. In theory the coupling factor increases without limit

but, in practice, saturation occurs at larger values of β_0 than shown in FIG. 7.

As the bubble size is increased the value of K increases in accordance with equation (6), but the coupling factor $f_{(D)s}$ decreases. Thus as seen in FIG. 7, curve **22** for a value of $K = 2$ show a much smaller coupling factor for increasing values of β_0. Curves **22** and **24** illustrate the responses for $K = 5$ and 10 respectively.

Thus, the damper can be designed to many selected coupling factor values. If desired, optimum or maximum coupling is achieved by utilizing the resonant curve **28**. It is to be understood that this curve applies to the damper forms of either FIGS. **4** or **5**.

In general, the analysis and operation of the rectangular tube damper shown in FIG. **5** are similar to that of the toroidal damper of FIG. **4**. The internal pressures balance the acceleration forces in similar manner as the toroidal system. However, in the longitudinal directions, along the legs **18***a* and **18***b* the viscous drag differs from the drag in the short legs **19***a* and **19***b*, and longitudinal pressures will develop. In addition, fluid flow around the corners of the rectangular damper, preferably provided with smoothly curved bends, normally develops vortex-type velocities transverse to the tube, that is, undesirable flow in the direction perpendicular to the walls of the tube rather than parallel to the walls of the tube.

However, such vortex-type velocities are considered sufficiently small that their effect are negligible and therefore can be neglected. Therefore, the equations of fluid motion in the tube will include a pressure term which has been utilized in the design formulae presented above. It has been discovered that the damper effectiveness factor for a rectangular damper is smaller than that of the toroidal type of damper of analogous geometric size. The relationship of the two types of dampers can be expressed by the following equation:

$$f_{(D)s}(\text{rect}) = (1-\delta^2)\, f_{(D)s}(\text{toroid}) \qquad (7)$$

where

$$\delta = (a-b)/(a+b)$$

a and b being the dimensions of the rectangular dampers shown in FIGS. **3** and **5**. The rectangular damper performance also depends on the rectilinear moments of inertia I_R defined by the following equation:

$$I_R = 4ab(a+b)\pi r_0^2 \rho \qquad (8)$$

The table which follows shows the relative performances of toroidal and rectangular dampers on basis of the same mass of fluid in each damper type.

Configuration	$I_{(D)}$	f_s
Circular	1	1
Rectangular, a/b=1	0.616	1
a/b=2	0.547	8/9
a/b=3	0.461	3/4
a/b=4	0.394	16/25

The centrifical effects of a bubble (FIGS. **4** and **5**) impose pressure forces on the fluid motion thereby changing the fundamental characteristics of the damper assembly. The dynamic effects arise from the sharp density change at the liquid surface. The forces, as has been indicated above (FIG. **7**), can attenuate (large values of K) or enhance (low values of K) the damping action of the assembly. It is desirable in the design of the damper that the bubble be large enough to establish a void across the entire tube area. The surface tension effects, as well as the temperature and thus density gradients along the viscous fluid path are considered negligible.

It can be shown that for a single toroidal damper with a bubble, the coupling factor may be expressed by the following equation:

$$f_{(D)s} = \tfrac{1}{2}\ \alpha_{imag} / [(1-K)^2 + k^2\ \alpha\ ^2 + 2K(1-K)\alpha_{real}] \qquad (9)$$

where α is defined by equation (3) above and where

$$K = (\omega_o/\omega)^2\, \theta_0/\pi \qquad (10)$$

As previously indicated, the toroidal and rectangular dampers can be arranged to develop a resonant condition with a bubble chosen in relation to the other parameters of the damper. Consideration must be given, of course, to the temperature co-efficient of expansion and contraction of the fluid so that the effects of low temperature conditions exhibited in space travel are minimized. This can be done by allowing for the contraction phonomenon of the viscous fluid or by selecting a viscous fluid that is relatively insensitive to temperature changes. It should be understood, furthermore, that the bubble may be defined by a fluid having a density and viscosity less than the more dense and viscous fluid (**12**). Thus, in such a system the enhanced coupling is still achieved but at a lower factor then for a system with a bubble of gaseous form whereby the density and viscosity would be very small compared to the viscous fluid.

According to the invention, a damper of asymetrical form can be arranged to provide a still more effective coupling factor in a fluid resonant environment. In one design which shall now be described, the effectiveness of such a damper is in the order of 10 to 1, such that a 4 lb. damper, including the weight of the viscous fluid, developed the same nutation damping effect as a 40 lb. damper of the type illustrated in FIG. **2**. Such a damper is shown in FIG. **6**.

The damper **30** formed of a hollow generally U-shaped tube has a relatively thin arcuate portion **32**, a pair of enlarged end cap portions **34**, and a much thinner straight tube portion **36**. Tube **36**, thus, provides a vapor line to prevent vapor lock. The plane of damper **30** is suitably mounted perpendicularly to the roll or yaw axis, with the spin axis **3** in the extension of the plane of the damper as indicated in FIG. **6**.

The geometry of the damper includes the length, l, of the arcuate portion **32**, having a cross-sectional area A_t. The cap **34** has a length sufficient to contain the fluid needed and a cross-sectional area A. The distance l_s is from the end cap **34** to the spin axis. The distances l_1 and l_2 are respectively that between the end caps **34** to the fluid surfaces of each end. When there is dynamic unbalance causing thereby fluid displacement, l_1 and l_2 are unequal. The fluid displacement is defined by the distance X.

The angular momenta of the two portions **32** and **34** of the damper are L_1 and L_2 the total angular momentum is $L_T = L_1 + L_2$.

Utilizing these relations,

$$L_T = \frac{IV_o}{R}\left[\frac{2\alpha - (K_\mu A/A_t)(1-\alpha)}{2-2K_\mu(1-\alpha)}\right] e^{-j\omega t} \qquad (10)$$

where

I = the rotational inertia of the fluid **12**;

V_o = the velocity of the tube wall;

R = the average radius of the damper, where the arcuate portion **32** is assumed to be a semicircle;

α = is defined by equation (3) above; and

K_μ is the desired factor.

The rotational inertia of I of equation (10) may be also represented by the following equation:

$$I \equiv \rho R^2 A_t (1 + l_1 + l_2) \quad (11)$$

Substituting equation (11) in equation (10) and solving K_μ results in the relation:

$$K_\mu \equiv 2(A_t/A)(\omega_0/\omega)^2 l_s/l \quad (12)$$

K_μ is analogous to K for the toroid, the difference in the two being solely that of the geometry of the damper, which is apparent by comparing equation (6) with (12).

By appropriate mathematical operations the effectiveness, or viscosity coupling factor of the U-shaped damper **30** is derived to be:

$$f_{(D)s} = \frac{1}{2} \text{ imaginary } \left[\frac{2\alpha - (K_\mu A/At)(1-\alpha)}{2 - 2K_\mu(1-\alpha)}\right] \quad (13)$$

A plot of K_μ for the value of **1** is shown in FIG. **8**, which illustrates graphically the relation of the coupling factor $f_{(D)s}$ as a function of the characteristic number as explained above for FIG. **7**.

The U-shaped form of damper provides a much greater range of design choices as will be better appreciated from the curves representing the relationships just explained.

The curves of FIG. **8** show the manner in which the factor $K_\mu = 1$, which, it is noted, is the condition of fluid resonance, causes the coupling factor to change as a function of the ratio of the area of the cap end **34** (A) to the area tube **12** (A_t), or the length **1** to the moment arm l_s and the velocities of nutation to spin.

Thus it will now be appreciated the effectiveness of a U-shaped damper **30** can be selectively designed to any of the values indicated.

The U-shaped damper device in operation is caused to be spun about the spin axis **3** while being oriented in a plane perpendicular to the axis desired to be damped. In practice two such dampers are used, one for each of the nonspinning axes. In operation of the U-shaped device of FIG. **6**, in general, the fluid **12** is caused to be displaced in a radially outward direction from the spin axis causing thereby the void or bubble in the tube **36** to be oriented between the respective surfaces of the fluid. For the toroidal forms illustrated by FIGS. **4** and **5** the bubble **13** will be disposed radially inward of the spin axis if the toroids are spun about an axis as shown for the U-shaped damper of FIG. **6**.

For the toroidal forms of the damper spinning about an axis through their symmetrical center (FIGS. **4** and **5**), the location of the bubble **13** may be in the positive or negative direction of the spin axis **3**. Indeed, it is possible that the bubble **13** may be divided between both ends of the spin axis within the damper. Although such splitting of the bubble is not preferred, the effectiveness of the damper is not seriously impaired.

Any wobble or nutation of the spacecraft which will be reflected by nutation of the spin axis will cause the fluid to be displaced from its symmetrical relation about the spin axis. The displacement of the fluid will be periodic following the nutation frequency. The movement of the fluid against the walls of the damper generates friction to dissipate the energy of nutation. The approximate damping time may be represented by the following relationship:

$$\tau = [\sqrt{I_{11} I_{22}/f_{(D)s}}]/I_D \cdot H \quad (14)$$

where I_D is defined by equation (11) and H is the total moment of inertia of the spacecraft. I_{11} and I_{22} are the moments of inertia about the roll and yaw axes respectively.

Referring again to the damper **30** as shown in FIG. **6**, the fluid **12** is positively caused to be displaced outwardly from the spin axis leaving the void or bubble in the tube portion **36** and any additional space required, depending upon the amount of fluid **12**, in the end cap portions **34**. Any nutation of the spin axis **3** will cause a displacement of the fluid from the equilibrium reference line **35** so that the distance l_1 is not equal to l_2. The displacement of one leg of the fluid being thus indicated by X as shown in FIG. **6**.

The displacement of the fluid following the nutation of the spin axis generates a periodic oscillation at the nutation frequency. The energy dissipation about the spin axis by the action of the fluid against the wall of the tube occurs in a manner similar to that of the toroidal forms of the damper.

For spacecraft that are not spinning, means may be provided to create artificially the spin required to provide the centrifical forces required for the operation of the viscous damper.

Referring to FIG. **9** there is shown a spacecraft **11** having a stabilizing wheel **40** de-coupled from the spacecraft by bearings **42** and rotated by a motor **44** about a shaft **46**. A gear **48** on shaft **46** coupled to a pinion gear **50**, drives the damper **30** rigidly attached to a shaft **52**. The rotation direction (ω_0) of the stabilizing wheel **40** is in the direction shown by the arrow **54**. Thus by the relation of the gears the damper **30** is rotated in the opposite sense as indicated by arrow **56**. The speed ratio of the damper **30** to the spin wheel or stabilizing wheel **40** may be arranged to any suitable and desired value. The speed of the motor can be utilized as a tuning means for resonance as indicated by the equations for K and K_μ. Thus, the damper **30** may function as a tunable damper on a stabilized platform that does not have sufficient spin to develop the necessary centrifugal forces to effect the necessary oscillation of the fluid to cause viscous damping.

FIG. **10** shows another manner in which the damper **30** may be provided with an artificial spinning environment. The stabilizing wheel **40** operates in a similar manner indicated above for FIG. **9**. Instead, however, of using a direct connection from the stabilizing wheel power drive system, a second motor **58** is arranged to drive or rotate the damper **30** about a shaft **60**. The spinning rate can be made to any desired requirement.

It will thus be appreciated that there is provided a means for adjusting the nutation damping rate of a viscous damper of generally toroidal or U-shaped form by selectively changing the size of the bubble. It should be understood that the void or bubble may include

fluids of less viscosity and density than the damping fluid.

A feature of the invention in the U-shaped form provides a means for tuning to the nutation damping rate by merely varying the ratio of the area of the end caps to the tube portion or the length of the tube to the moment arm.

What is claimed is:

1. A nutation damper device adapted for rotation about an axis parallel to the spin axis of a spin stabilized body comprising:

a. a hollow tube formed generally within a plane;

b. viscous fluid in a portion of said tube, said fluid having a selected density and viscosity;

c. the remaining portion of said tube having a fluid of less viscosity and substantially less density than said viscous fluid;

c1. the size of said remaining portion being selected so that the resonant frequency of said viscous fluid is substantially equal to the frequency of said nutational motion, and

d. means for mounting said tube relative to said body so that said fluid is displaced radially outwardly from said rotation axis, said remaining portion being oriented thereby between the respective surfaces of said fluid when said tube is rotated about said rotation axis,

e. whereby the viscous fluid will resonate in said tube at a frequency substantially equal to the frequency of nutation of said body.

2. A device according to claim 1 wherein the tube is a toroid having circular cross-section.

3. A device according to claim 1 wherein the tube is a rectangle having circular cross-section.

4. A device according to claim 1 wherein said tube is cylindrical formed generally as a U, the ends of the tube being enlarged, and sufficient viscous fluid in said tube to fill only a portion of said enlarged ends.

5. A device according to claim 4 wherein said end portions are open and are joined to each other by a conduit serving as a vapor line to prevent a vapor lock.

6. A device according to claim 4 wherein the coupling factor ($f_{(D)s}$) is proportional to the ratio of the area of the cross-section of said tube and the enlarged ends of said tube.

7. A device according to claim 4 wherein the coupling factor ($f_{(D)s}$) is selected to a desired value by varying the spin rate of said body.

8. A device according to claim 4 wherein the coupling factor ($f_{(D)s}$) is proportional to the ratio of the length of the tube to the distance of the tube from the spin axis.

9. A device according to claim 1 wherein said viscous fluid is taken from the class comprising silicone oils or equivalents, the remaining portion of said tube comprising vapor of said fluid.

10. A device according to claim 1 wherein said body is a de-spun satellite, having a momentum wheel decoupled from a stable platform, and rotated by a motor, and further including on said platform means for spinning said tube about an axis perpendicular to said spin axis.

11. A device according to claim 10 wherein said spinning means includes means coupled to said motor.

12. A device according to claim 10 wherein said spinning means includes a second motor.

13. A device for damping nutational motion about a given axis, comprising:

a hollow tube formed into a closed loop and defining generally thereby a plane having a rotation axis, said tube being adapted for orientation for rotation about said axis parallel to the spin axis of a spin stabilized body, said tube being partially filled with a viscous fluid which flows with respect to the inner surface of the tube in response to said nutational motion, the portion of said tube free of said fluid defining a space of predetermined size, the size of said space being selected so that the resonant frequency of said fluid in said tube is substantially equal to the frequency of said nutational motion.

14. A device according to claim 10, wherein the direction of flow of said fluid within said tube is parallel to a given plane, said given axis being perpendicular to said plane.

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