This invention pertains to a space vehicle directing apparatus of the type where a torque is applied to an inertia member suspended in the vehicle whereby an equal and opposite reaction torque tends to turn the vehicle in space.

An object of this invention is to suspend a spherical rotor by means of high electric fields and then to apply magnetic fields to induce a current in the rotor, causing a torque on the rotor whereby an equal and opposite reaction torque is applied to the space vehicle. Suspension of the rotor with electric fields eliminates need for close tolerance bearings and minimizes friction; using a spherical rotor reduces the number of inertia members to one.

This and other objects and advantages will become more apparent when a preferred embodiment of this invention is considered in connection with the drawings in which:

FIGURE 1 is a plan view of an assembled apparatus for producing the electric and magnetic fields to suspend and turn a rotor within;

FIGURE 2 is a section taken through 2—2 of FIGURE 1 with the rotary ball removed showing electric field plates and magnetic field windings;

FIGURE 3 is a view in perspective of the device shown in FIGURE 1 with one of the eight outer sections being removed.

FIGURE 4 is a schematic diagram showing one series resonant circuit; and

FIGURE 5 is a schematic diagram showing four series resonant circuits.

A preferred embodiment of this invention will now be described with the aid of FIGURES 1-5 in the drawings.

In the plan view of FIGURE 1 there are visible four sections, 20, 21, 22 and 23, bolted together along their inner faces. Likewise, there are four sections, 24, 25, 26, 27, visible in FIGURES 2 and 3, beneath sections 20–23 and bolted thereto along their common faces to form a housing 28 for a rotor therein, which in this embodiment, is a hollow stainless steel ball 29 but may, of course, be solid and/or consist of other materials.

Sections 20–27 are then fastened to the vehicle frame, not shown.

Attached to each of the eight sections 28–27 are plates to which a high voltage is applied. Plates 30, 31, 34 and 37 are shown in FIGURE 2 and are attached to sections 20, 21, 24 and 25, respectively. Similar plates are attached to sections 22, 23, 26, and 27. Each plate is in the shape of a spherical triangle so that it conforms to the surface of ball 29. Also, each plate is connected to a high voltage terminal which extends through and is supported by its corresponding section to a high voltage source 39. High voltage terminals 40, 41, 42 and 43, which are attached, respectively, to sections 20, 21, 22 and 23, are shown in FIGURE 1, and terminals 45 and 46, which are attached, respectively, to sections 24, 25, 26, and 27, are shown in FIGURE 3. A high voltage from source 39 of alternately opposite polarities is applied to the terminals so that in FIGURE 1 terminals 40 and 42 would have a negative polarity applied thereto and terminals 41, 43 would have a positive polarity applied thereto.

The high voltage plates, such as plates 30, 31, 34 and 37, are closely spaced to the rotor and induce a polarity opposite to the polarity applied to the particular plate, causing an attractive force therebetween. The spacing in one embodiment is 0.010 inch. Since there are eight high voltage plates symmetrically placed about the rotor, proper control of the voltages will permit the rotor to be suspended therebetween and free to rotate in any direction with no mechanical friction. This is accomplished without the use of bearings to not only simplify construction and reduce the need for very close tolerances but also to eliminate mechanical friction. The fields required to suspend such a ball would be very small in space since gravity is a small factor.

It is desirable to keep the ball 29 centered between the plates even during vehicle acceleration or deceleration. This can be done by providing source 39 means for measuring the capacitance between each plate and the rotor 29 and adjusting the voltage to that plate, accordingly. For example, if the ball came too close to plate 31, the capacitance between it and the ball 29 would increase thereby decreasing the voltage to the plate 31 and attracting between plate 31 and ball 29. At the same time the ball 29 moves toward plate 31, it will be moving away from the plate diametrically opposite plate 31 decreasing the capacitance, increasing the voltage and attractive force between ball 29 and the diametrically opposite plate. Thus, there are changed forces between two plates and the ball 29 which tend to restore it to a central position.

A second way of maintaining ball 29 centered will be explained in connection with FIGURE 4. Only two plates 31, 32 are shown for the sake of simplicity but it is to be understood that there are three other pairs of plates connected in this manner. An alternating voltage source 47 is connected in series with resistance 48 and inductance 49 which is connected to plate 31, with plate 32 being connected to the other side of generator 47.

The capacitance between plates 31, 32 and ball 29 complete the series resonant circuit. The frequency from source 47 is higher than the resonant frequency of ball 29 is centered. However, when the ball 29 goes off center, the capacitance in the series resonant circuit changes thereby changing the voltage at plates 31, 32.

Movement of ball 29 towards plates 31, 32 will decrease the voltage at plates and movement away will increase the voltage.

In a suspension system having eight plates, each of four series resonant circuits are connected to two plates in the manner shown in FIGURE 5. Circuits 52 and 54 are each connected to adjacent plates covering the top hemisphere of ball 29 and circuits 56, 58 are each connected to adjacent plates covering the bottom hemisphere of ball 29. It should be noted in source 59 means for ball 29 are centered. However, when the ball 29 goes off center, the capacitance in the series resonant circuit changes thereby changing the voltage at plates 31, 32. Movement of ball 29 towards planes 31, 32 will decrease the voltage at plates and movement away will increase the voltage.

In a suspension system having eight plates, each of four series resonant circuits are connected to two plates in the manner shown in FIGURE 5. Circuits 52 and 54 are each connected to adjacent plates covering the top hemisphere of ball 29 and circuits 56, 58 are each connected to adjacent plates covering the bottom hemisphere of ball 29. It should be noted in source 59 means for ball 29 are centered. However, when the ball 29 goes off center, the capacitance in the series resonant circuit changes thereby changing the voltage at plates 31, 32. Movement of ball 29 towards planes 31, 32 will decrease the voltage at plates and movement away will increase the voltage.

Ball 29 may also be suspended magnetically where magnetic fields are applied to magnet pole faces arranged around a magnetic ball. Also, suspension may be accomplished by using a pressurized air bearing between rotor and housing. In addition it is believed that the magnetic field provided by the stators to rotate the ball.
3,260,475 S as will be discussed, can also be used to suspend the ball. An opening 50 is formed at the center of each side of housing 28 to make six openings in all, one on each side. A terminal plug 51 is inserted through each opening 50. The plugs 51 are bolted to plates 52 which in turn are bolted to the corresponding sections which they abut. Two of the terminals are removed in the view of FIGURE 3 to clearly show openings 50.

Fixed to the interior of housing 28 are six stator coil windings, each of which has an arc slightly less than a semicircle. Windings 54, 55, 56, 57 and 50 are shown in FIGURE 2. The stator windings are in three mutually perpendicular planes with the point of intersection of said planes coinciding with the center of ball 29 when suspended. For example, windings 54 and 55 lie in one plane, windings 56 and 57 lie in a second plane perpendicular to the first plane, and winding 58 and its complementary winding, not shown, lie in a third plane perpendicular to the first two planes. The stator windings preferably lie in the same spherical plane as, and are located between, the eight high voltage plates, and the ends of each winding in one perpendicular plane about the center portion of the windings in a second perpendicular plane and in turn have their center portions abutted by the ends of windings in the third perpendicular plane.

Each winding has conductive wires interwound in a core of magnetic material with the wires being connected to corresponding terminal plugs 51. A polyphase alternating current source 60 is applied to plugs 51 with the phase of the signal applied to the individual plugs 51 varying in accordance with the desired direction of rotation of ball 29. When an alternating polyphase signal is applied to terminals 51, a current is induced in sphere 29 in a manner similar to the current induction in the well-known induction motor. The induced currents interact with the changing magnetic field to provide a torque to turn the ball 29. By controlling the signals to terminals 51 of the proper stator windings, torque may be applied to ball 29 in any desired direction and magnitude and an equal and opposite torque will be applied to the stator windings, and to the space vehicle, to turn the space vehicle in the desired direction. Therefore, by applying torque to a single member, that being ball 29, and direction of flight may be obtained for a space vehicle. This improves over systems using a separate member, such as a reaction wheel, for each of the three dimensions to control space vehicle direction.

**Operation**

The operation of this embodiment will be briefly described. The housing 28, composed of identical sections 20–27, is fixed to a space vehicle frame. A ball 29 of conductive material is suspended in housing 28 by means of a high voltage applied to terminals formed in each of the sections 20–27 as terminals 41, 45, 46 and 43 shown in FIGURE 3. Each high voltage terminal is fixed to a plate in the form of a spherical triangle with plates 30, 31, 34, 37 being shown in FIGURE 2, and with each of the plates conforming to the surface of the ball and closely spaced thereto. By applying voltages of alternate polarity to the high voltage terminals, such as terminals 41, 44, 43, etc., a charge is induced on the surface of ball 29 which is equal and opposite to the charge on the plates 30, 31, 34, 37 etc. This causes a mutual attraction in a plurality of areas on the ball 29 and suspends the ball between these attractions. This provides an frictionless, bearing free construction. The ball 29 is maintained in a centered position by varying the voltage to the respective plates according to the capacitance change between the plates and the ball 29.

Means to turn the suspended ball 29 are in the form of a plurality of substantially semicircular stator coil windings 54, 55, 56, etc., which are fixed to housing 28 and placed about sphere 29 in three mutually perpendicular planes. Each winding 54, 55, etc. is then connected to a corresponding terminal 51 to which is applied a polyphase alternating voltage. Application of an alternating signal to terminals 51 will cause a varying magnetic field about the coil windings, inducing a current in rotor 29, to turn the rotor corresponding to the strength of signals applied to terminals 51 in much the same manner as the rotor of an induction motor is caused to turn. Since the windings are in three mutually perpendicular planes, any direction of rotational torque can be imparted to the ball. This will cause an equal and opposite rotational torque on the housing 28 and the attached space vehicle to turn the vehicle in any direction with only one revolving member, that being ball 29.

Although this invention has been disclosed and illustrated with reference to particular application, the principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

Having thus described my invention, I claim:

1. Apparatus for direction control of a vehicle comprising electrically conductive unitary rotor means, means for suspending said unitary rotor means for rotation in more than one plane, winding means to rotate said unitary rotor means in more than one plane being placed adjacent said unitary rotor means, means to supply an alternating polyphase winding means to induce a current in said unitary rotor means to impart a torque to said unitary rotor means, one of said winding means and unitary rotor means being connected to the vehicle frame so that an equal and opposite torque is applied to said vehicle to control the attitude of said vehicle.

2. Apparatus for direction control of a vehicle comprising an electrically conductive spherical rotor, means for suspending said rotor for rotation in more than one plane, winding means to rotate said rotor means in more than one plane being placed closely adjacent said rotor surface and lying in three mutually perpendicular planes which intersect at the center of said suspended rotor, means to apply alternating current to said winding means in each plane according to varying power supplied to said rotor, said winding means being fixed to the frame of said vehicle, said rotor being suspended relative to said vehicle so that any torque existing between said winding means and rotor will tend to control the attitude of said vehicle.

3. Apparatus for direction control of a vehicle comprising an electrically conductive rotor, a variable power source, rotor suspension means conforming to at least a portion of the surface of said rotor and being connected to said variable power source to suspend said rotor, means connected to said variable power means to sense the relative position of said rotor and said suspension means varying said power means to maintain said rotor in a predetermined position relative to said suspension means, said winding means placed adjacent said rotor, means to supply an alternating current to said winding means to induce a current in said rotor to cause said rotor to turn, said winding means being connected to the vehicle frame so that an equal and opposite torque is applied to said vehicle to control the attitude of said vehicle.

4. The apparatus of claim 3 wherein said variable power source is a variable voltage source, said sensing means measuring the capacitance between said rotor and said portions to vary the voltage to said portions in proportion to the capacitance changes.

5. The apparatus of claim 3 wherein said rotor is spherical and said portions comprise eight spherical equilateral conductive triangles each approximately equal in area to one-eighth of the total surface area of said spherical rotor.

6. The apparatus of claim 3 with said winding means being placed closely adjacent said rotor surface and lying
in three mutually perpendicular planes which intersect at the center of said rotor when suspended.

7. The apparatus of claim 3 wherein said alternating current is polyphase.

8. The apparatus of claim 6 wherein in each of said mutually perpendicular planes are two substantially semicircular windings on a magnetic core, the ends of the semicircular windings in one plane facing the center portions of the semicircular windings in a second plane, the semicircular windings in said one plane being faced by the ends of the semicircular windings in the third plane, each of said semicircular windings being connected to said alternating current supply means.

9. The apparatus of claim 1 wherein said means for suspending said rotor means comprises a voltage source, a plurality of conductive members being adjacent said rotor, resonant circuit means being connected between said voltage source and said members, said voltage source being of a frequency higher than the resonant frequency of said circuit so that said capacitance between the rotor and said conductive members increases, the voltage to said portion will increase.

10. The apparatus of claim 1 wherein said means for suspending said rotor means comprises a voltage source, a plurality of conductive members being adjacent said rotor, resonant circuit means being connected between said voltage source and said members so that as the capacitance between the rotor and said conductive members increases, the voltage to said portion will increase.

11. The apparatus of claim 10 with said resonant circuit means and said power means comprising a plurality of circuits each having an inductance, a resistance and voltage source, each of said circuits being connected to a pair of said members.

12. The apparatus of claim 11 wherein there are four of said members placed about each hemisphere of said rotor means with each pair of connected members covering substantially one half of a hemisphere, the connection between members in each pair covering one half of one hemisphere of the rotor means being rotated 90° about an axis perpendicular to the said hemisphere relative the connection between members covering the other half of the hemisphere of said rotor means.

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