United States Patent

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[73] Assignee **The United States of America as represented by the Secretary of the Army**

[54] **THRUST-PRODUCING GYRO SYSTEM**
6 Claims, 3 Drawing Figs.

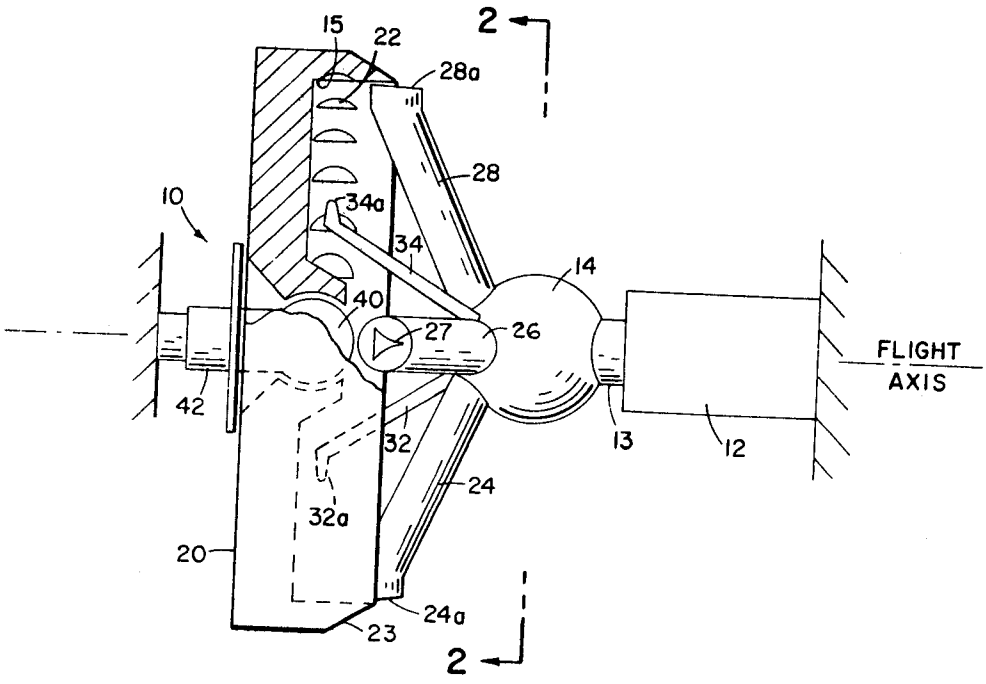
[52] **U.S. Cl.** **244/3.2,** 137/38, 74/5
[51] **Int. Cl.** **B64c 15/04,** F42b 15/02, F42b 15/18
[50] **Field of Search** 244/3.2

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ABSTRACT: A thrust-producing gyro system for attitude control of missiles. The gyro system guides a missile along a path determined by the attitude of a space-oriented rotating wheel without using intermediate amplifiers. The gyro system includes a hot gas source that supplies gas to a housing enclosing a plenum chamber. The chamber has a pair of tubular members radially disposed for providing gas flow to the inner surface of a high-momentum wheel for rotation thereof. Additional tubular members extend radially from the plenum chamber to terminate adjacent the interior annular surface of the high-momentum wheel and provide gas flow which is exhausted from the tubes at ports in the missile skin adjacent the end of each tube. The output gases spin the wheel at a high momentum. The rotating wheel covers a portion of each tube outlet so that relative motion between the missile and wheel varies the gas escaping from each tube, increasing the gas escaping from one port while decreasing the gas escaping from an opposing port, and thereby provides a restoring force to the missile.



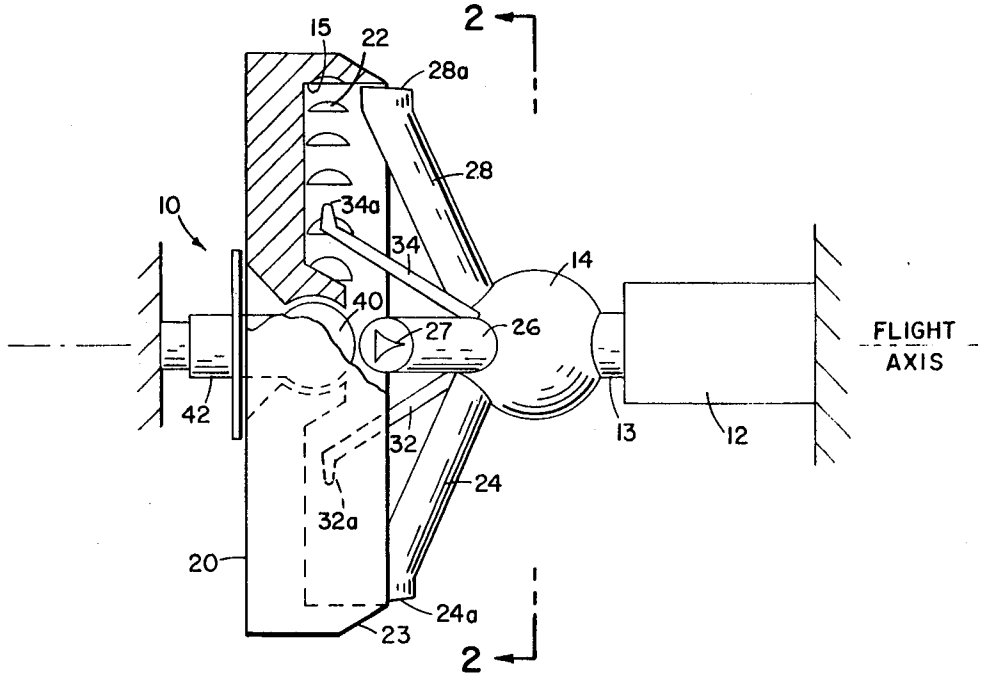


FIG. 1

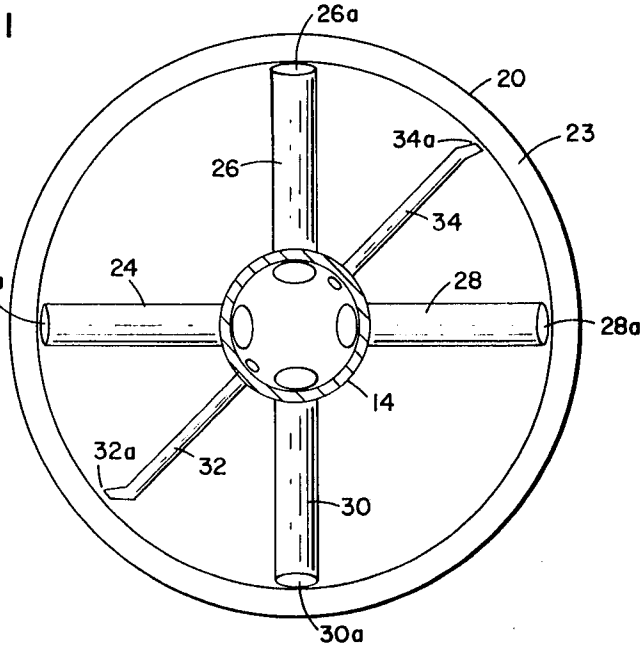


FIG. 2

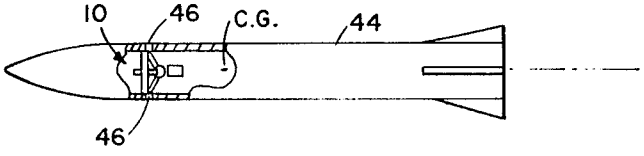


FIG. 3

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THRUST-PRODUCING GYRO SYSTEM

SUMMARY OF THE INVENTION

The apparatus of the present invention is a device for providing attitude control of missiles or projectiles and does not require additional amplifier stages to pick up and amplify deviation of the projectile from the desired flight path. The thrust-producing gyro system utilizes a free rotor to provide two degrees of freedom and thereby provide pitch and yaw control of the projectile. The momentum of the rotor, rotating wheel, is high enough to minimize the effect of torques associated with the flow of controlling gases. The gyro is brought up to speed and is uncaged at launch of the projectile and maintains the projectile on a course normal to the plane of the spinning wheel. A gas generator supplies hot exhaust gas to a housing containing a plenum chamber. The plenum chamber has a pair of tubular members disposed radially therefrom for providing gas flow therethrough to the inner surface of the high-momentum wheel to develop and maintain the rotation thereof. A plurality of tubular passageway forming control members extend radially from the plenum chamber and terminate adjacent the inner surface of the missile, with the distal or terminating end thereof being partially covered by an edge of the rotating wheel. Control jets in the form of exhaust ports are provided in the terminating end of each tube to exhaust gas through the outer surface of the missile or projectile. The rotating wheel, which covers a portion of each of the control jets so that relative motion in the projectile and wheel increases and decreases gas flow, varies the gas escaping to the projectile surface and thereby provides a restoring force thereto. With the projectile on course, gas escaping from the control jets is equal in all jets and the forces therefrom on the missile are balanced, providing no restoring force. The output exhaust gases provide directional control between the wheel and the missile on a plane perpendicular to the missile flight axis.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a preferred embodiment of the invention.

FIG. 2 is a view along line 2—2 of the embodiment of FIG. 1.

FIG. 3 is a view of a missile incorporating the invention therein.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings wherein like numerals represent like parts in all figures, there is disclosed a preferred embodiment of the invention in FIGS. 1 and 2. A thrust-producing gyro system **10** comprises a hot-gas generator **12** that is connected to a housing **14** enclosing a plenum chamber. Gas generator **12** is disposed for directing gases into the plenum chamber through a tubular member **13**. A plurality of tubular passageway forming control members **24, 26, 28** and **30** are secured to housing **14** in communication with the plenum chamber. Members **24, 26, 28,** and **30** extend radially outwardly from housing **14** and terminate adjacent the interior annular surface **15** of a high-momentum wheel **20** that is rotatably supported on the missile support structure as described hereinbelow. Tubular members **24, 26, 28** and **30** are provided with exhaust portions **24***a*, **26***a*, **28***a* and **30***a* on the distal ends thereof. These exhaust portions or ports are positioned in normal relation to the missile longitudinal axis and are partially covered by the interior surface of the wheel. Each of members **24, 26, 28** and **30** are spaced 90° from adjacent members on a plane perpendicular to the missile flight axis. Member **24** is located adjacent members **26** and **30** and is diametrically opposite member **28**. A series of indentations **22** or buckets are disposed around the inside circumference **15** of wheel **20**. Wheel **20** is rotatably mounted on a spherical bearing **40** having a shaft **42** attached thereto. For example, wheel **20** may rotate on ball bearings or air bearings (not shown). Shaft **42**, generator **12** and plenum chamber housing **14** are fixed within a missile or other vehicle and are coaxial with the missile flight axis.

A pair of spin nozzles **32** and **34** is provided for directing jets of gas against indentations **22** on wheel **20** to impart spin thereto and to maintain spin thereof. Spin nozzles **32** and **34** comprise a pair of tubular passageway forming members having one end secured to housing **14** in communication with the plenum chamber. The distal ends of spin nozzles **32** and **34** include end portions or ports **32***a* and **34***a*, respectively, which are disposed inside wheel **20**, in normal relation to the missile axis to direct gases against indentations **22** on surface **15**.

The thrust-producing gyro system must be brought up to speed while in a caged position. This is done before the missile **44** (FIG. 3) is launched. Caging, in general, is along the rocket axis. Wheel **20** is limited by shaft **42**, allowing from 5°–10° of motion to either side of the shaft, for example. Missile **44** is committed to a particular trajectory path as determined by the situation involved and gas generator **12** is ignited. Generator **12** may be ignited by any convenient means such as a squib rupture type disk or a gas piston (not shown) driven from the main missile generator. When generator **12** is ignited, hot gases therefrom are introduced into plenum chamber housing **14**. The pressure building up in chamber **14** escapes through the exhaust and spin ports. Gas from spin ports **32***a* and **34***a* bring wheel **20** up to the desired r.p.m., which may vary depending on the range and bearing design employed therein. While the rotating wheel is brought up to speed and thereafter, the hot gases escaping from exhaust ports **24***a*, **26***a*, **28***a* and **30***a* are balanced. At this initial reference or null position, the edge **23** of spinning wheel **20**, covers a portion of the four exhaust or control jets. Because of the equal gas flow in all exhaust ports, the wheel spin axis coincides with the missile flight axis, maintaining the plane of the spinning wheel perpendicular to the flight axis.

The thrust-producing gyro **10**, as noted in FIG. 3, is mounted to the structure of missile **14** in front of the center of gravity CG. Spinning wheel **20** has an outer diameter that is slightly less than the inner diameter of the missile skin. Openings **46** in the skin of missile **44** are aligned with exhaust ports **24***a*, **26***a*, **28***a* and **30***a*, thus allowing the escaping control gases to exhaust from the missile at a specific place.

Launching of the missile uncages the gyro wheel **20**. Prior to launch the missile is maintained in a relatively fixed position which prevents movement of the missile support structure with respect to spinning wheel **20**, caging the wheel. Supported by bearing **40** and shaft **42**, wheel **20** is activated by gas escaping from the spin and output ports, gas from the spin ports imparting wheel rotation and gas from the output ports stabilizing the wheel position before launch. Hence, the unlaunched missile cages the spinning wheel, and launching of the missile uncages the wheel by allowing movement between the support structure and the wheel. Any tendency of missile **44** to deviate from an axis normal to the plane of wheel **20** after launching of the missile causes a restoring force to be applied to the missile. For example, deviation of the fore end of the missile in the general direction of port **24***a* causes a restoring force from port **24***a* to be applied. As missile **44** drifts off course, generator **12**, chamber **14** and bearing **40** drift proportionally since they are fixed to the missile structure. Wheel **20** is free to move with respect to bearing **40** and therefore remains unmoved from the caged position of revolution as bearing **40** drifts with the missile. This relative movement of bearing **40** and chamber **14** causes port **24***a* to become more uncovered and port **28***a* to be more covered by spinning wheel **20**. The additional gas pressure being ejected out port **24***a* couples with the reduced gas pressure of port **28***a* to force the nose of missile **44** toward the axis of spinning wheel **20**, thereby returning the missile to its original path or course. During the restoring action the gas escaping from ports **26***a* and **30***a* will vary but will not provide a restoring effect when drift is directly toward port **24***a* or **28***a*.

Obviously, missile drift in the direction of a particular quadrant formed by the ports will bring about restoring action

from all ports. For example, fore end drift of missile **44** into the quadrant formed by ports **24***a* and **26***a* will result in wheel **20** covering more of the exhaust ports **28***a* and **30***a* and simultaneously uncovering more of ports **24***a* and **26***a*. A restoring force will then be provided by each control jet and will be proportional to the amount of drift toward the particular jet. An increase in gas flow will be provided by ports **24***a* and **26***a* with a respective decrease in gas flow from diametrically opposed control or exhaust ports **28***a* and **30***a* returning the missile to the flight path.

In the event that gas escaping from ports **46** on the missile surface increases turbulence or provides intermittent control due to airflow around the nose of the missile, or for other reasons, the gyro system can be mounted in the rear of the missile. The thrust-producing gyro system **10** would be rotated 180° so that generator **12** is toward the front of missile **44** and wheel **20** is toward the rear. Drift of the nose of missile **44** in the direction of control port **24***a* causes port **24***a* to move under the edge **23** of wheel **20** thus reducing the gas escaping therefrom and increasing the gas output of port **28***a*, thereby restoring the missile to the flight path.

The exhaust ports may employ linear or nonlinear gate valves. The logarithmic shaped valve **27** on port **26***a* of FIG. **1** provides a linear gas flow with respect to the position thereover of wheel **20**. All exhaust ports employ the same type of valve opening to insure balanced outputs therefrom.

Wheel **20** is capable of obtaining velocities above 10,000 r.p.m., depending on the bearing design. The edge **23** of wheel **20** that passes over the four exhaust ports is tapered to minimize torques that are transferred to the wheel by aeroballistic lift forces perpendicular to the gas flow. The tapered edge **23** prevents a large vacuum area and offsets the tendency of gas flow to pull the edge of wheel **20** over jet opening **27**, thereby providing more positive control over the missile flight path.

It is obvious from the foregoing disclosure that a more elaborate system may be employed using the identical principles. For example, six exhaust ports may be used and spaced at 60° from adjacent ports, and additional spin jets may be used. More than one thrust producing gyro system may be used to provide a more rapid response by adjusting both fore and aft ends of the missile simultaneously. A system may employ eight exhaust ports with four balanced nonlinear ports and four balanced linear ports. Similarly three exhaust ports at **120** degree intervals may be employed to provide a more slowly responding but equally successful system. Various other combinations and modifications of the thrust-producing gyro system may be readily apparent to those skilled in the art.

I claim:

1. A thrust-producing gyro for attitude control comprising: a hot-gas generator, a plenum chamber having an input port connected to said generator and having a plurality of output ports for conveying gas therethrough, a high-momentum wheel mounted adjacent to said output ports for providing two degrees of freedom and disposed for rotation responsive to impingement thereon by gases from certain of said output ports, other of said output ports being adapted for differential closing and porting respectively, thereby guiding a projectile or moving vehicle along a predetermined path normal to the plane of the wheel and controlled by the attitude thereof, said other output ports include at least four exhaust or control jets for conveying gas therethrough at a uniform velocity to be exhausted therefrom to the outer surface of said projectile, an inner annular edge of said rotating wheel covers at least a portion of said control jets, and each of said control jets are equidistant from adjacent jets so that relative motion in the projectile and the wheel will decrease the flow in one or more jets while increasing the flow in the opposing jets to provide a restoring force to the projectile, and wherein the exhaust from said jets is on a plane perpendicular to the flight axis of said projectile.

2. A thrust-producing gyro as set forth in claim **1** wherein the outer edge of said rotating wheel that passes over the control jets is tapered to minimize the torques being transferred to the wheel by lift forces perpendicular to the gas flow, the inner surface of said wheel includes a series of indentations therearound adjacent to one edge thereof, and wherein said output ports further include at least two spin jets that eject gas to said indentations to bring the wheel up to speed and to maintain the wheel speed.

3. A thrust-producing gyro as set forth in claim **2** and further comprising a spherical bearing, and wherein said generator, plenum chamber and spherical bearing are fixed with respect to said projectile, said rotating wheel is free to move on said spherical bearing, and said control jets have a logarithmic rate of change of port area or opening, shaped to provide a linear flow function as the wheel position varies thereover.

4. A thrust-producing gyro for attitude control comprising: a hot-gas generator, a plenum chamber having an input port connected to said generator and having a plurality of spin and output ports for conveying gas therethrough, a high-momentum wheel mounted adjacent to said output ports for providing two degrees of freedom and disposed for rotation responsive to impingement thereon by gases from said spin ports, said output ports being adapted for differential closing and porting respectively, thereby guiding a projectile or moving vehicle along a predetermined path normal to the plane of the wheel and controlled by the attitude thereof, said output ports comprise four tubular passageway forming control members extending radially outward from said chamber and having exhaust or control jets in the distal ends thereof, said exhaust jets are spaced 90° apart on a plane perpendicular to the flight axis of said projectile and convey gas therethrough to be exhausted to the outer surface of said projectile, an inner edge of said rotating wheel covers at least a portion of said control jets so that relative motion in the projectile and the wheel will decrease the flow in one or more jets while increasing the flow in the opposing jets to provide a restoring force to the projectile, the inner surface of said wheel includes a series of indentations therearound adjacent to one edge thereof, said spin ports include two tubular passageway forming control members extending radially outward from said chamber and having spin nozzles or ports on the distal end thereof disposed adjacent the interior annular surface of said wheel to direct gases against said indentations to initiate and control the wheel spin rate.

5. A thrust-producing gyro as set forth in claim **4** and further comprising a spherical wheel support bearing, and wherein the edge of said wheel that passes over the control jets is tapered on the outer edge to minimize torques being transferred to the wheel by lift forces perpendicular to the gas flow, said rotating wheel is free to move on said spherical bearing, said gas flowing through said control jets provides pitch and yaw control to maintain the projectile on a course normal to the plane of the wheel, and said generator, plenum chamber and spherical bearing are fixed with respect to said projectile.

6. A thrust-producing gyro as set forth in claim **5** wherein the control jets have a logarithmic rate of change of port area or opening, shaped to provide a linear flow function as the wheel position varies thereover.