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(54) Title: THRUST-PRODUCING DEVICE WITH DETONATION MOTOR

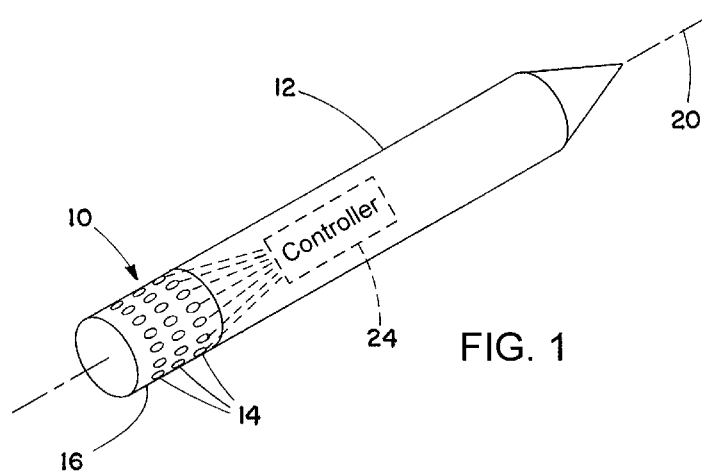


FIG. 1

(57) Abstract: A detonation thrust-producing device (10) includes an explosive (32) located in a recess (34) in an external surface of a body (16). Detonation of the explosive expels material out of the recess, providing thrust to the body in an opposite direction. A mass, such as a metal disk (58), may be placed blocking or covering the external opening. The body may be a part of a vehicle, such as an airborne projectile (12). The thrust-producing device may include multiple detonation motors arrayed around the body, capable of being individually or multiply detonated. Such thrust-producing devices may be used for attitude adjustment, steering, or other control of the flight of the projectile or other air vehicle. The detonation thrust-producing devices have the advantage of a faster-response time than propellant-based devices, and do not need the nozzles that are used with many propellant-based devices.

THRUST-PRODUCING DEVICE WITH DETONATION MOTOR

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The invention is in the field of thrust-producing devices.

DESCRIPTION OF THE RELATED ART

[0002] Many sorts of devices are used for producing thrust for a variety of purposes. Traditional rocket motors use sustained combustion of solid or liquid propellants in combination with a supersonic nozzle to accelerate the exhaust products to high velocities, creating a reaction force. However such rocket motors are not suitable for providing reaction forces over very short timeframes.

SUMMARY OF THE INVENTION

[0003] A thrust-producing device uses one or more detonation motors with explosives, to generate thrust over very short timeframes.

[0004] According to an aspect of the invention, a thrust-providing device includes: a body; and a detonation motor. The detonation motor includes an explosive in a recess in an external surface of the body. Detonation of the explosive provides thrust to the body opposite to the direction that material is expelled from the recess, through an external opening in the body.

[0005] According to another aspect of the invention, an aircraft includes: a body; and detonation motors circumferentially spread around a perimeter of the body. Each of the detonation motors includes an explosive in a recess in an external surface the body, wherein detonation of the explosive provides thrust to the body opposite to a direction that material is expelled from the recess, through an external opening in the body.

[0006] According to yet another aspect of the invention, a method of steering an object includes the steps of: detonating an explosive in a recess in a body of the object; and expelling gasses generated by the explosive, thereby creating thrust on the object.

[0007] To the accomplishment of the foregoing and related ends, the invention comprises the features hereinafter fully described and particularly pointed out in the

claims. The following description and the annexed drawings set forth in detail certain illustrative embodiments of the invention. These embodiments are indicative, however, of but a few of the various ways in which the principles of the invention may be employed. Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The annexed drawings, which are not necessarily to scale, show various aspects of the invention.

[0009] Fig. 1 is an oblique view of a thrust-producing device in accordance with an embodiment of the invention, as part of an aircraft.

[0010] Fig. 2 is a cross-sectional fragmentary view of part of the device of Fig. 1, showing details of a detonation motor of the device.

[0011] Fig. 3 is an oblique view of the device of Fig. 1, showing a first step in a method of using the device to change course.

[0012] Fig. 4 is an oblique view illustrating a second step of the method.

[0013] Fig. 5 is an oblique view illustrating a third step of the method.

[0014] Fig. 6 is a cross-sectional fragmentary view, showing details of an alternate embodiment detonation motor.

[0015] Fig. 7 is a view of a device in accordance with another alternate embodiment of the present invention.

DETAILED DESCRIPTION

[0016] A detonation thrust-producing device includes an explosive located in a recess in an external surface of a body. Detonation of the explosive expels material out of the recess, providing thrust to the body in an opposite direction. A mass, such as a metal disk, may be placed blocking or covering the external opening, such as in the recess between the explosive and the external opening. The body may be a part of a vehicle, such as an airborne projectile. The thrust-producing device may include multiple detonation motors arrayed around the body, capable of being individually or multiply detonated to provide thrust to the body in different amounts and/or in different directions. Such thrust-producing devices may be used for attitude

adjustment, steering, or other control of the flight of the projectile or other air vehicle. The detonation thrust-producing devices have the advantage of a faster-response time than propellant-based devices, and do not need the nozzles that are used with many propellant-based devices.

[0017] Fig. 1 shows a detonation thrust-producing device 10 that is part of an airborne vehicle or aircraft 12 (intended to broadly include all types of flying things or devices, including space vehicles), such as a projectile or missile. The device 10 may be used to steer the aircraft 12, producing small bursts of thrust from detonation motors 14 around the perimeter or circumference of a body 16 of the aircraft 12. The small bursts of thrust may be produced in any of various directions to cause a corresponding reaction in the aircraft 12. As described in greater detail below, small explosive devices in the detonation motors 14 are ignited to produce the bursts of thrust.

[0018] The thrust-producing device 10 may have detonation motors 14 able to provide thrust in any of a variety of directions. The detonation motors 14 may be circumferentially spread around a perimeter of the body 16, and/or there may be multiple rows of detonation motors 14 at the same circumferential locations, separated in a direction of a longitudinal axis 20 of the device 10. The device longitudinal axis 20 may also be the longitudinal axis of the aircraft 12, as in the illustrated embodiment. The detonation motors 14 may be arrayed in a limited number of circumferential locations about the perimeter of the body 16. For example, the detonation motors 14 may be at four circumferential locations equally spaced about the perimeter of the body 16, or eight equally-space locations, or any other number of suitable locations of suitable spacing.

[0019] The detonation motors 14 are coupled to a controller 24 that controls selective activation of the detonation motors 14. The controller 24 may detonate one or more of the detonation motors 14 as needed, to provide thrust to change the course and/or orientation of the aircraft 12. The controller 24 may be used to activate detonation motors 14 to provide thrust in a desired direction, and may control the number of detonation motors 14 activated in order to control the level of thrust provided. The controller 24 may include integrated circuits or other suitable devices, to be used in making a determination or otherwise controlling activation of the detonation motors 14. The controller 24 may be in communication to other

devices external to the aircraft 12, such as ground stations or aircraft that fire or simply control the aircraft 12, to receive signals regarding movements of a target to be intercepted by the aircraft 12, or another desired location to be achieved by the aircraft 12.

[0020] One possible use of the thrust-producing device 10 is in altering course of the aircraft 12 to intercept a moving target, such as an incoming projectile. For such a purpose rapid course correction is greatly desired, since little time may be available for correcting course in order to intercept the incoming projectile.

[0021] Other uses are possible for the thrust-producing device 10. It may be used on any of a variety of aircraft for any of a variety of purposes. The thrust-producing device 10 may also be used on other sorts of devices, for a variety of purposes. Examples of other such devices include satellites and torpedoes. Instead of having detonation motors 14 with different orientations, as an alternative all of the detonation motors 14 (or even a single detonation motor 14 that is the only detonation motor, in another embodiment of the device 10) may provide thrust in only a single direction. An example of such an embodiment is in a small missile or munition, which may involve control over thrust in a single axis, for example as a means of throttling. Instead of smoothly or continuously modulating thrust of a motor, a thrust-producing device can produce small increments of thrust.

[0022] Turning now to Fig. 2, details are shown of one of the detonation motors 14. The detonation motor 14 includes an explosive 32 that is located in a recess 34 in the body 16. In the illustrated embodiment the recess 34 is a cylindrical recess, with a circular cross section shape, and oriented substantially perpendicular to an outer surface 35 of the body 16. Alternatively the recess 34 may have any of a variety of other shapes and/or orientations.

[0023] The recess 34 has an external opening 36 where it is open to a region 38 external to the body 16. The recess 34 also may have an internal opening 42 that puts the recess 34 into communication with an interior cavity 34 that is enclosed by the body 14. The internal opening 42 may allow access from the bottom of the recess 34 to a detonator 44 that is used to detonate the explosive 32. The internal opening 42 is blocked by a filler 48 that is in a bottom portion of the recess 34, in order to prevent egress from the internal opening 42 of pressurized gasses or other

products of the detonation of the explosive 32. The filler 48 may be a suitable potting material.

[0024] A casing 50 surrounds explosive 32 and the filler 48. The casing 50 holds the explosive 32 and the filler 48 in place and aligned. The casing 50 may be made of suitable metal, for example being made of bronze gilding metal, or aluminum.

[0025] The detonator 44 may have wires 52 or other communication devices for connection to the controller 24 (Fig. 1). The wires 52 may pass through the internal opening 42. Alternatively the controller 24 may communicate with the detonator using various other sorts of communication methods, for example using fiber optic cables or wireless communication methods, such as the sending and receiving of suitable radio frequency (RF) signals.

[0026] The external opening 36 may also be blocked or covered, preventing direct communication between the explosive 32 and the external region 38. In the illustrated embodiment this is accomplished by a projectile or mass 58 that is in a part of the recess 34 that is closest to the external opening 36. Alternatively the projectile 58 may be outside of the recess 34, covering the external opening 36. Detonation of the explosive 32 expels the projectile or mass 58 clear of the body 16, into the surrounding region 38.

[0027] The use of the projectile mass 58 may aid in maximizing thrust output from the detonation motor 14. The projectile 58 may have a mass that is about half the mass of the explosive 32. More broadly, the projectile 58 may have a mass that is from 0.1 to 2 times the mass of the explosive charge 32, although other ratios are possible. Such a charge mass (explosive) may provide a specific impulse (thrust integral divided by propellant mass) of at least 175 seconds, with projectile/explosive mass ratio of about 0.5 providing a specific impulse of 220 seconds. It is possible that higher projectile/explosive mass ratios may be used, producing a lower specific impulse, where volume efficiency considerations are important.

[0028] The projectile 58 may be made of any of a variety of suitable materials, such as metal or plastic, and may have any of a variety of characteristics, such as being solid or being pressed powder. The projectile 58 may have a disk shape, or another shape with a circular cross section, to fit the circular-cross-section recess 34. Alternatively the projectile 58 may have a different cross-section shape,

particularly one that corresponds to a non-circular-cross-shape of an alternative recess.

[0029] Advantageously, there may be no need for any sort of sealing between the projectile 58 and the walls of the recess 34. The explosive 32 detonates, as opposed to burning, so it generates pressurized gasses very quickly, for instance in 10% or less of the time to burn a corresponding amount of propellant.

[0030] The detonation motor 14, with its explosive 32, provides many other advantages over propellant-based thrusters. Explosives detonate, in contrast to the burning that occurs in propellants. Burning of a solid propellant is governed by chemical kinetics and reaction rates. These kinetics are specific to the propellant formulation being used. The gas generated by burning of a solid propellant is then generally accelerated through a nozzle to supersonic exit velocities. Since the momentum thrust generated by a propellant-based thruster is equal to the mass flow rate times the velocity, the higher the velocity, the higher the thrust generated by a given mass flow. Therefore a nozzle is an important part of a propellant-based thruster. Dispensing with the nozzle in a propellant-based thruster significantly reduces performance, since the velocity is significant lower if there is no nozzle present.

[0031] In contrast operation of the detonation motor 14 involves detonation of the explosive 32. Detonation is not burning, but instead is a reaction that propagates through an explosive material, such as the explosive 32, at the speed of sound for the medium. When the explosive 32 is detonated, it provides enough momentum for the pressurized gasses to be expelled from the recess 34 at a velocity at least that of a traditional rocket motor (the propellant-based nozzle-using thruster described above), but with the advantage that no nozzle is needed. Being able to achieve good performance without a nozzle means a smaller, lighter, and less expensive thruster motor.

[0032] In addition, explosives that are detonated have higher densities than solid rocket motor propellants. This results in the detonation motor 14 having a higher volumetric efficiency than an equivalent propellant-based thruster. The detonation motor 14 also has the advantage of greater impulse per unit volume. For instance, density specific impulse may be greater than a factor of two or more using the detonation motor 14. Typical propellants have a density specific impulse of about

400 g-sec/cc, while in an embodiment of the detonation motor 14, the density specific impulse was over 1800 g-sec/cc.

[0033] Detonations occur at least one order of magnitude faster than even fast-acting thrusters that use solid propellants. For example the detonation motor 14 can act in microseconds, as opposed to seconds. This faster action allows for finer control, and smaller impulse quanta. For example, 100 detonation micro-thrusters can be activated in the time it takes to fire 10 traditional solid-propellant-based thrusters. The firing of multiple micro-thrusters may be sequential, rather than simultaneous, due to the amount of energy required to fire multiple thrusters. A firing circuit used to fire multiple thrusters may need time to recharge between firings of individual or groups of thrusters.

[0034] The explosive material for the explosive 32 may be any of a variety of suitable explosives. Examples of suitable explosive materials include CL-20, DBX-1, HNS-IV, and lead styphnate. Other high explosive materials, such as RDX, HMX, TATB, LX-14, LX-17, LX-19, or PBXN explosives, may also be used.

[0035] As noted, the filler 48 may be a suitable potting compound. Examples of suitable potting compounds are epoxies and glasses.

[0036] Figs. 3-5 show the thrust-producing device 10 in operation. Fig. 3 shows the aircraft 12 traveling a first direction 70. In Fig. 4 several of the detonation motors 14 on one side of the thrust-producing device 10 are fired, expelling pressurized gasses and their projectile 58 in the region around the aircraft 12. This produces a reaction force 74 on the aircraft 12, which changes the course of the aircraft 12 to the direction 78 shown in Fig. 5.

[0037] The aircraft 12 may have other common structures, some of which may also be used for maintaining or changing course. For example the aircraft 12 may include any or all of wings (or other lift-producing devices), canards, ailerons, rudder(s), elevators, and elevons. The aircraft 12 may include a propulsion system, such as rocket motor, jet engine, or other thrust-producing device. Alternatively the aircraft may be unpowered.

[0038] Fig. 6 shows an alternate embodiment thrust-producing device 110, which has a detonation motor 114. The detonation motor 114 is in a recess 134 in a body 112. The recess 134 is packed with an explosive 132 that is free, when detonated, to expel pressurized gasses substantially unhindered through an external opening

136 to an external region 138 that is outside of the body 112. In contrast to the detonation motor 14 shown in Fig. 2, the detonation motor 114 does not have anything corresponding to the projectile 58 (Fig. 2) of the detonation motor 14. The detonation motor 114, when compared with the detonation motor 14, has less weight and fewer parts, and does not expel any solid items when detonated. However, the detonation motor 114 may not perform as well (e.g., produce as much thrust) as the detonation motor 14.

[0039] Fig. 7 shows still another embodiment, a spherical device 210 that has a series of detonation motors 214 placed around its surface. The device 210 is "spherical" in the sense that it has a generally round shape, which may have facets, such as circular or polyhedral flat portions. The detonation motors 214 are located all along the surface of the spherical device 214, and may be symmetrically spaced about the spherical surface.

[0040] The detonation motors 214 may have the characteristics of the detonation motors 14 and 114 (Figs. 1 and 5, respectively) described above. The detonation motors 214 may be able to provide thrust to steer the device 210 in any of a wide variety of directions.

[0041] The device 210 may have any of a variety of suitable sizes, and may be used for accomplishing any of a variety of goals. In one embodiment, the spherical device 214 may be a throwable object, for example about the size of a softball or large hand grenade, which could be maneuvered after throwing toward a target. For example the device 210 may be a thrown munition that could be maneuvered around a corner, while in flight, by firing appropriate of the detonation motors 214. Suitable communication and control systems could be used to guide the device 210 in this way.

[0042] The above description only discusses a few of the possible configurations and potential uses of the thrust-producing devices and detonation motors described. Many other variations are possible.

[0043] Although the invention has been shown and described with respect to a certain preferred embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular regard to the various functions performed by the above described elements

(components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.

CLAIMS

What is claimed is:

1. A thrust-providing device comprising:
a body; and
a detonation motor;
wherein the detonation motor includes an explosive in a recess in an external surface the body; and
wherein detonation of the explosive provides thrust to the body opposite to a direction that material is expelled from the recess.
2. The thrust-producing device of claim 1, further comprising a detonator operatively coupled to the explosive to detonate the explosive.
3. The thrust-producing device of claim 2, wherein the detonator is operatively coupled to a control system that controls triggering of the detonator.
4. The thrust-producing device of any of claims 1 to 3, wherein the body has an interior opening that puts the recess into communication with an interior cavity of the body.
5. The thrust-producing device of claim 4, further comprising a filler between the explosive and the opening.
6. The thrust-producing device of claim 5, wherein the filler includes a potting compound.
7. The thrust-producing device of any of claims 1 to 6, further comprising a projectile operatively coupled to the explosive, wherein the projectile is expelled clear of the body when the explosive is detonated.

8. The thrust-producing device of claim 7, wherein the explosive weighs from 1 to 3 times what the projectile weighs.

9. The thrust-producing device of claim 7 or claim 8, wherein the projectile is a disk.

10. The thrust-producing device of any of claims 7 to 9, wherein the projectile is made of metal.

11. The thrust-producing device of any of claims 7 to 10, wherein the projectile is in the recess.

12. The thrust-producing device of any of claims 1 to 11, wherein the recess has a circular cross-section shape.

13. The thrust-producing device of any of claims 1 to 12, wherein the detonation motor is one of a multitude of detonation motors that are part of the thrust-producing device.

14. The thrust-producing device of claim 13,
wherein the thrust-producing device is part of an aircraft; and
wherein the thrust-producing device is used to steer the aircraft.

15. The thrust-producing device of claim 14, wherein the body of the thrust-producing device is part of an external surface of the aircraft.

16. The thrust-producing device of claim 14 or claim 15, wherein the detonation motors are circumferentially spread around a perimeter of the aircraft.

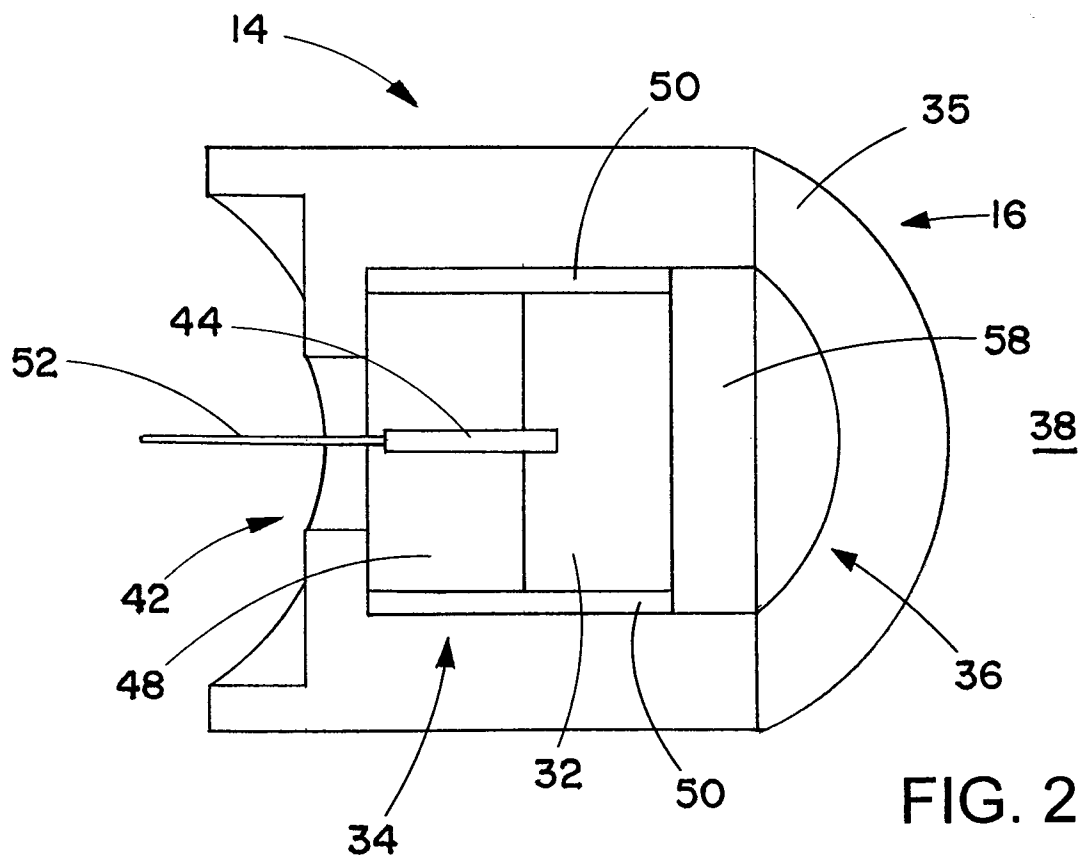
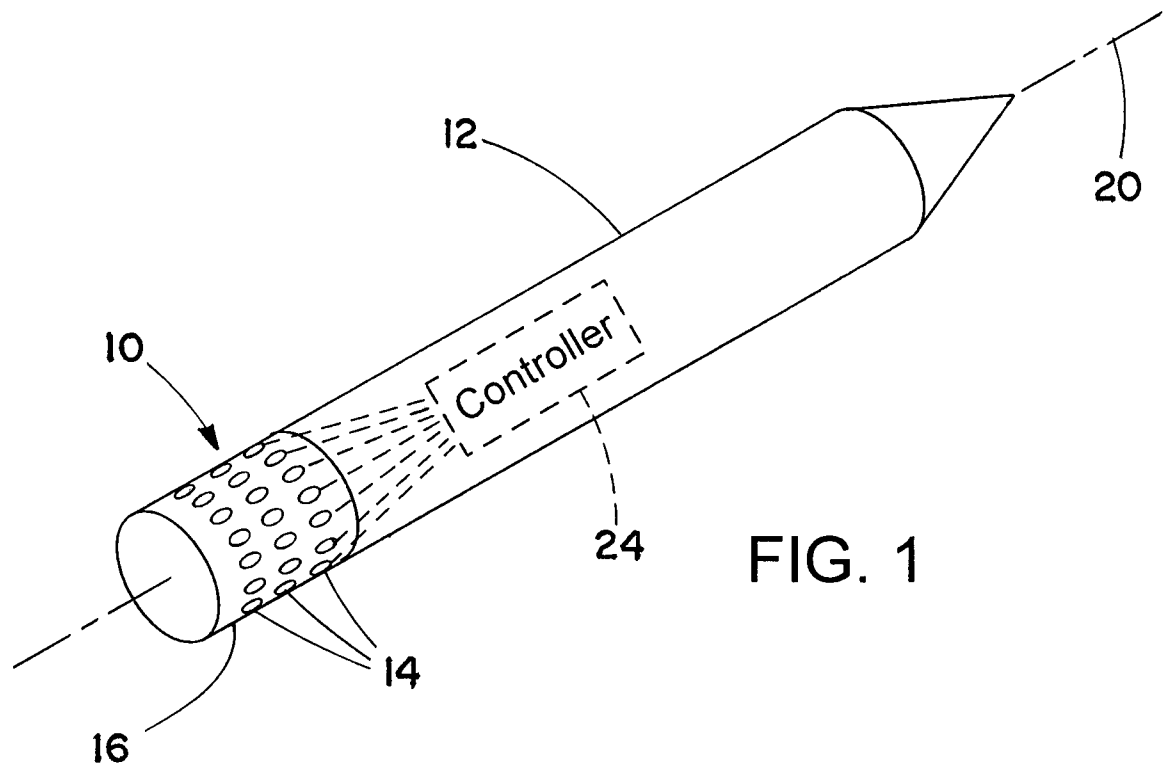
17. An aircraft comprising:
a body; and
detonation motors circumferentially spread around a perimeter of the body;

wherein each of the detonation motors includes an explosive in a recess in an external surface the body, wherein detonation of the explosive provides thrust to the body opposite to a direction that products from the detonation are expelled from the recess.

18. A method of steering an object, the method comprising:
detonating an explosive in a recess in a body of the object; and
expelling gasses generated by the explosive from the recess, thereby creating thrust on the object.

19. The method of claim 18, wherein the expelling gasses includes expelling a solid projectile using the gasses.

20. The method of claim 18 or claim 19, wherein the object is an aircraft, and the creating thrust is used for steering the object.



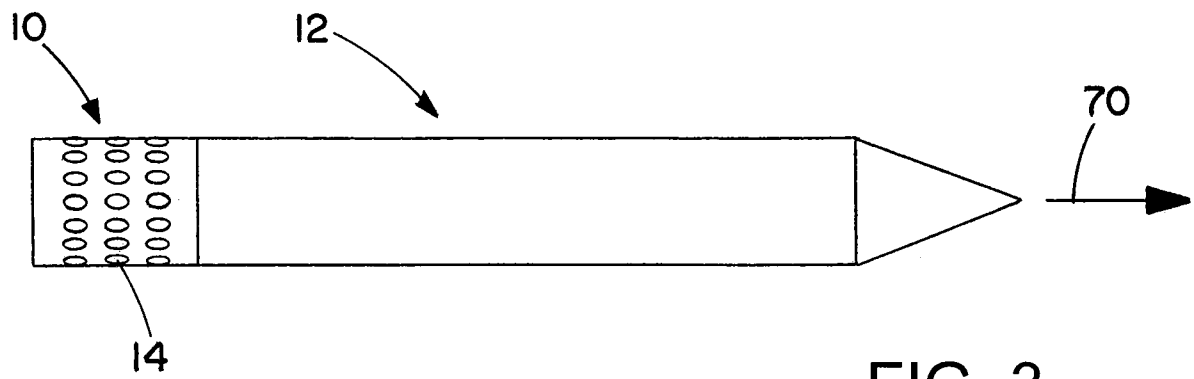


FIG. 3

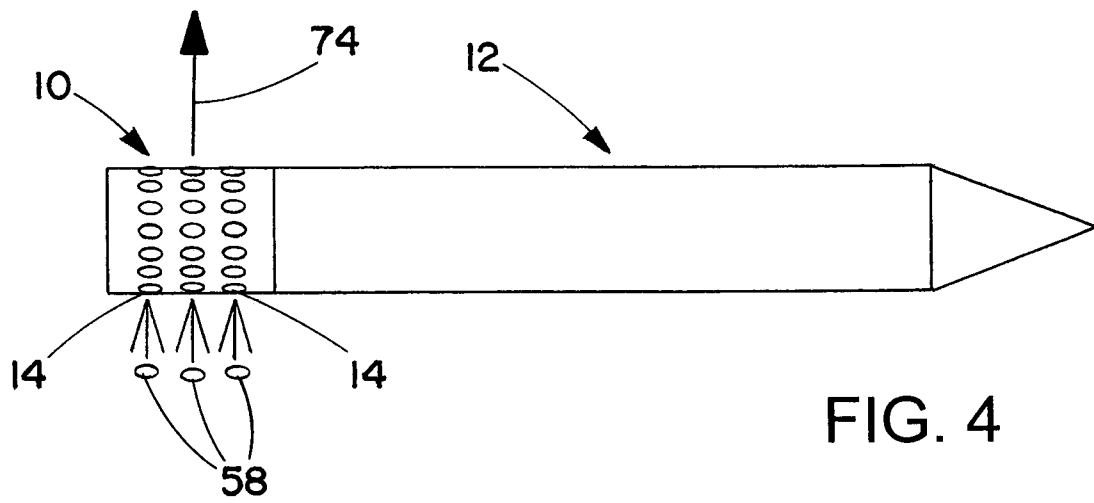


FIG. 4

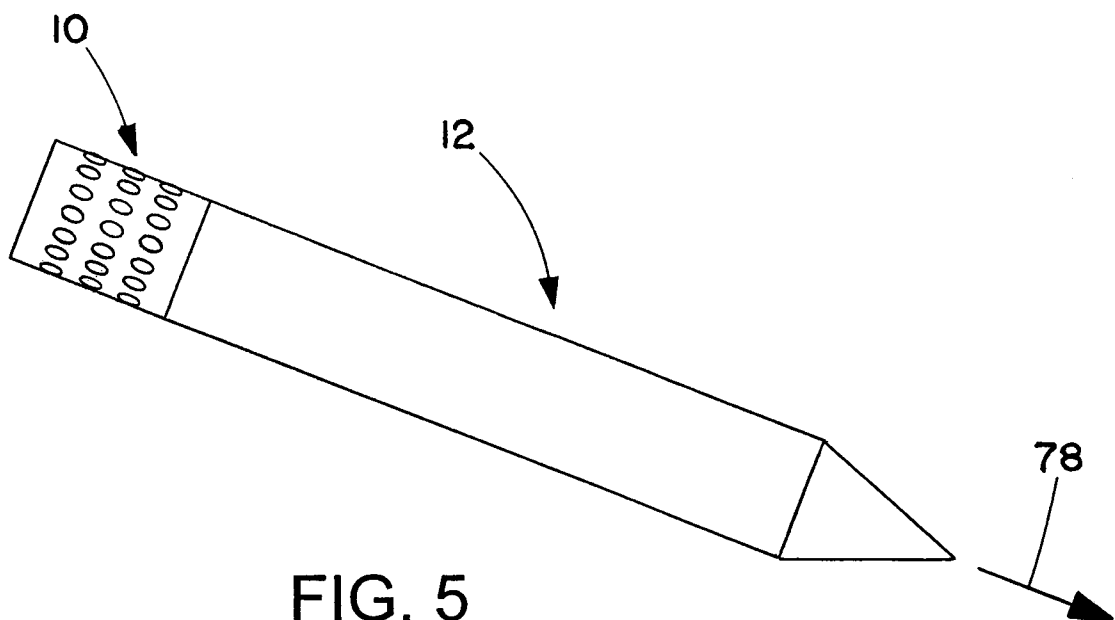
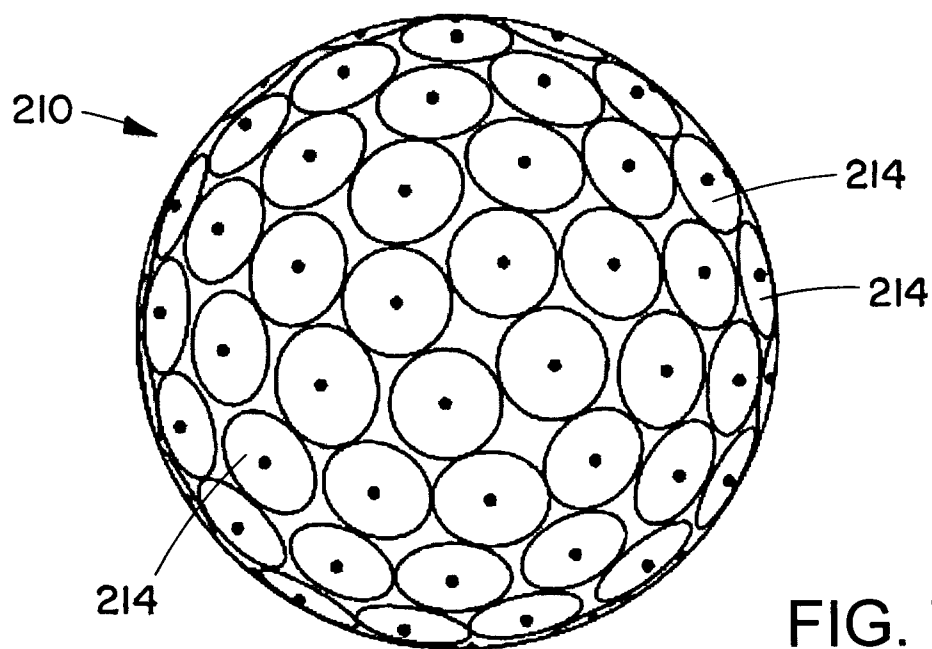
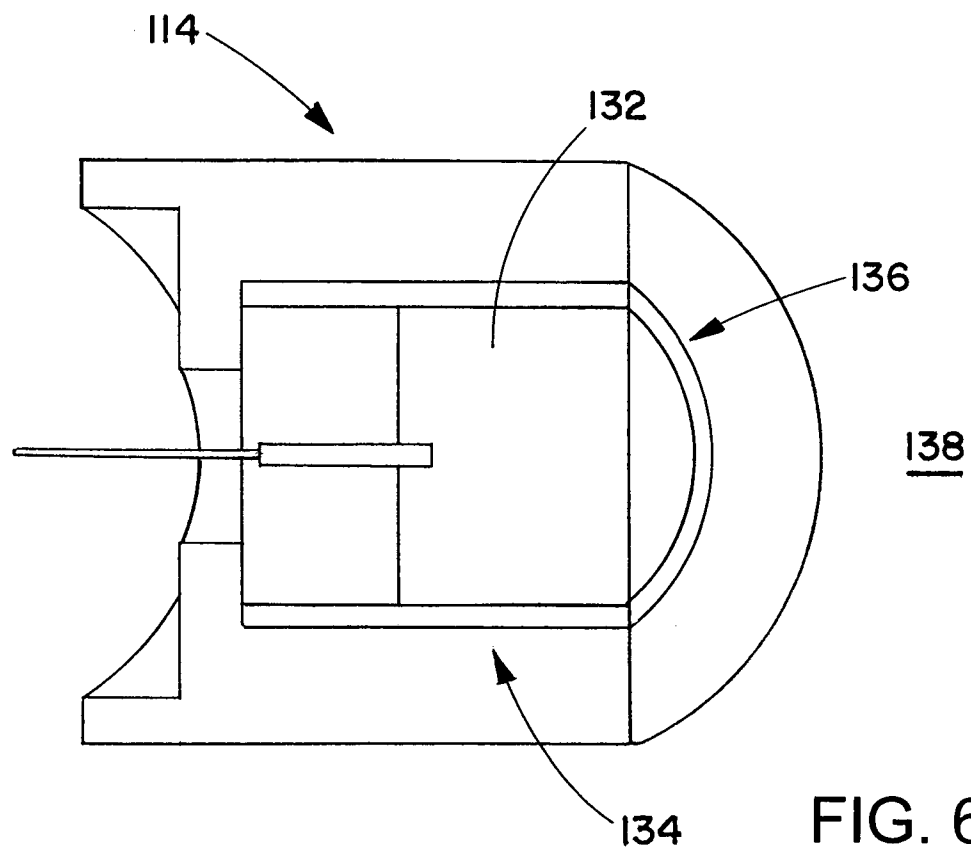


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/034910

A. CLASSIFICATION OF SUBJECT MATTER

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ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02K F42B B64G F02C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 054 712 A (BAR KLAUS [DE] ET AL) 8 October 1991 (1991-10-08) column 3, line 36 - column 4, line 42; figures 1,2	1-4,7-20
X	----- US 7 004 423 B2 (FOLSOM MARK [US] ET AL) 28 February 2006 (2006-02-28) column 3, line 24 - column 6, line 56; figures 1-6	1-20
X	----- US 4 444 119 A (CAPONI ELSO R [US]) 24 April 1984 (1984-04-24) column 1, line 54 - column 2, line 35; figures 1-2	1-20
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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20/02/2014

Name and mailing address of the ISA/

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Robelin, Bruno

INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 8 084 725 B1 (DRYER RICHARD [US] DRYER RICHARD L [US]) 27 December 2011 (2011-12-27) column 1, line 11 - column 7, line 34; figures 1-3 -----	1-3,7-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

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