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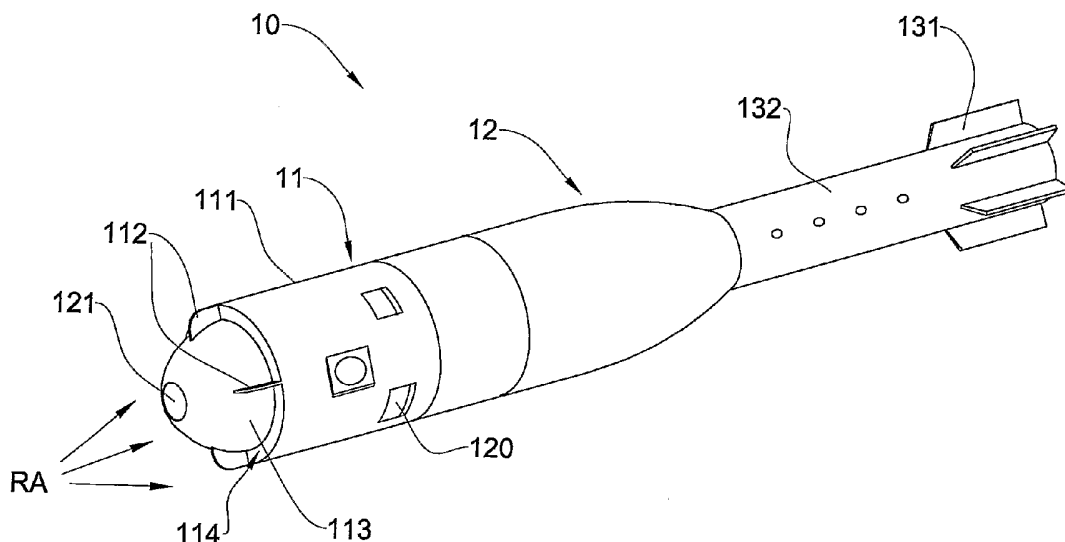
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(54) Title: STEERING SYSTEM AND METHOD FOR A GUIDED FLYING APPARATUS



(57) Abstract: A steering system for use in a traveling guided flying apparatus (10) and method for driving the steering system are provided. The system includes an outer housing (111), an inner housing (113) and a support fins (112) extending inwardly from the outer housing (111) and holding the inner housing (113) thereon. The outer housing (111) and the inner housing (113) define a ram air inlet (114) at a nose of the forward portion (11), an annular inlet air passage (115), an annular pressure chamber (116), and an outlet air passage (125). The steering system further includes exhaust outlets (120) arranged in the outer housing and separately controlled valves (124) mounted at the exhaust outlets (120) configured to vary the flow of escaping air through the exhaust outlets (120). The steering system also includes a target seeker (121), one or more pressure sensors (119) mounted in the pressure chamber (116) and a control unit (122) for controlling flight of the guided projectile (10).

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Steering system and method for a guided flying apparatus

FIELD OF THE INVENTION

This invention relates to the field of flying apparatus control systems, and in particular, to the area of projectile and missile steering through the use of ram air for lateral thrust control.

5

BACKGROUND OF THE INVENTION

Lateral steering control is an important feature in projectile guidance systems. Such control provides the ability to improve weapon accuracy and correct for initial aiming errors and target maneuvers.

10 Various lateral projectile control techniques are known in the art. One of such techniques is based on aerodynamic control, and include deflecting tail fins, canard lifting surfaces and other deflecting elements.

Another known technique is based on jet thrust control and include cold gas jet thrusters, warm gas jet thrusters, impulse thrusters and explosive thrusters. 15 These systems, for example, can employ side mounted exhaust outlets coupled to sources of highly pressurized gases through adjustable control valves. In the case of self-propelled missile, such sources are usually common to the fuel source of the missile. Whilst, in the case of fired projectiles, the sources dedicated to the steering function are separately ignited by an auxiliary device.

20 For example, U.S. Patent Nos. 4,726,544 and 5,044, 156 describe various steering systems for the final phase of a guided projectile. The steering is achieved by control jets acted upon by hot gas created in a combustion chamber.

U.S. Patent No. 4,573,648 teaches the use of ram air for thermodynamic ignition of a solid fuel. The steering system includes an open-ended diffusion

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chamber and an adjacent combustion chamber located in the nose of a projectile to receive ram air that ignites a solid fuel material within the combustion chamber. A pair of oppositely disposed lateral steering ports are provided aft of the combustion chamber and are interconnected therewith via a diverting valve that is controllable to selectively divert the escaping combustion gases from the combustion chamber to one or both of the steering ports to thereby change or maintain the trajectory course of the projectile after firing.

The systems which are dependent upon a propellant source carried onboard the missiles and/or projectiles face problems related to fuel exhaustion and shift in center of mass as fuel is used. These systems may also introduce the additional complexity associated with combustion chamber and fuel supply systems.

The use of ram air for lateral steering control instead of the gas created in a combustion chamber is also known in the art (see, for example, U.S. Pat. Nos. 4,522,357, 4,685,639 and 4,537,371).

For example, U.S. Pat. No. 4,522,357 teaches the use of ram air for steering a projectile which is fin stabilized and has a normal in-flight roll rate of about 1200 rpm. The ram air enters a nose opening in a projectile during projectile flight passes to a central chamber and is selectively diverted to laterally positioned and oppositely oriented steering jets. The steering jets are interconnected with the aft end of the central chamber. A diverting mechanism is located between the central chamber and each of the steering jets to allow either one or none of the steering jets to provide correctional steering forces when desired. The diverting mechanism includes a deflector mounted on a shaft and rotated in the opposite direction to that of the rotating projectile. In order to provide a differently directed thrust force, the deflector is rotationally driven at a different speed so that the steering thrust vector is redirected. The projectile is guided to the target via an information beam of energy radiated from a source at the firing location. The information beam contains relative location codes which are used together with vertical reference information derived from on-board roll reference sensor to correct the flight path of the projectile.

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U.S. Pat. No. 4,537,371 describes a small caliber guided projectile having a forward opening inlet which provides supersonic stream ram air to a flow control mechanism prior to exhausting such air through a pair of diametrically opposed bifurcated guidance nozzles. The flow control mechanism includes a primary flow passageway and orifice switching devices for controlling bypass flow to the exhaust nozzles. Means of vortex generation is located upstream of the discharge of the flow through switching devices into the nozzles. When the switching devices are closed, flow over the means of vortex generation generates a small vortex for triggering a boundary attachment flow as a result of the Coanda effect and increases flow through the nozzle. Opening of the orifice switching device results in aspiration through the nozzle, thereby impeding flow. By controlling the respective switching devices, flow through the opposed nozzles may be varied to produce a resultant lateral force on the projectile, permitting control of the trajectory of the projectile.

15

SUMMARY OF THE INVENTION

Despite the prior art in the area of projectile steering through the use of ram air for lateral thrust control, there is still a need in the art for further improvement in order to provide a steering system for use in a flying apparatus, such as a projectile, missile, etc., which is not rolling or rolling around its axis, and is able to fly at subsonic and/or transonic speed.

20

The present invention partially eliminates disadvantages of the prior art techniques and provides a steering system for use in a traveling guided flying apparatus, the system comprising:

25

an outer housing and an inner housing defining: a ram air inlet at a nose of the forward portion, an annular inlet air passage, an annular pressure chamber, and outlet air passage between an inside wall of the outer housing and an outside wall of the inner housing;

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a plurality of support fins extending radially inwardly from the outer housing and holding the inner housing thereon;

a plurality of exhaust outlets arranged in the outer housing;

a plurality of separately controlled valves mounted at the exhaust outlets;
5 the valves being configured to vary the flow of escaping air through the exhaust outlets;

a target seeker mounted at the nose of the forward portion and configured for sensing a target and producing a target sensor signal representative of the relative location of the target;

10 at least one pressure sensor mounted in the pressure chamber and configured for measuring the gas pressure therein and producing a pressure sensor signal representative of changes of gas pressure in the pressure chamber; and

a control unit mounted in the inner housing and operatively coupled to the controlled valves, the target seeker, and the pressure sensor, said control unit being
15 responsive to said target sensor signal and said pressure sensor signal, and configured for controlling flight of the guided projectile by generating a valve control signal and providing said valve control signal to said plurality of separately controlled valves;

an electrical power source module operable to provide electrical power
20 required for operating said target seeker, said at least one pressure sensor, and said plurality of separately controlled valves.

Examples of the flying apparatuses according to the present invention include, but are not limited to, projectile, missile, rocket, bomb, etc.

25 The steering system of the present invention has many of the advantages of the prior art techniques, while simultaneously overcoming some of the disadvantages normally associated therewith.

The steering system according to the present invention may be easily and efficiently manufactured.

30 The steering system according to the present invention is of durable and reliable construction.

– 5 –

According to another broad aspect of the present invention, there is provided a method for driving the steering system of the present invention. The method comprises:

- receiving ram air by the ram air inlet;
 - 5 directing said ram air through the air passage to the pressure chamber;
 - controllably releasing said ram air from the pressure chamber through said plurality of separately controlled valves arranged downstream of the pressure chamber by controllable operating said controlled valves, wherein said controllable operating includes:
 - 10 sensing the target and producing said target sensor signal required for homing in at the target;
 - measuring the gas pressure the pressure chamber and producing a pressure sensor signal representative of changes of gas pressure in therein;
 - and
 - 15 generating a valve control signal and providing said valve control signal to said plurality of separately controlled valves in response to said target sensor signal and said pressure sensor signal,
- thereby controlling flight of the guided projectile.

There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows hereinafter
20 may be better understood. Additional details and advantages of the invention will be set forth in the detailed description, and in part will be appreciated from the description, or may be learned by practice of the invention.

25 BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

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Fig. 1 is a perspective view of a guided projectile, in accordance with an embodiment of the present invention;

Fig. 2 is a longitudinal cross-sectional view of a forward portion of a guided projectile, according to one embodiment of the invention; and

5 **Fig. 3** is a cross-sectional view of the forward portion shown in **Fig. 2** taken along line I-I.

DETAILED DESCRIPTION OF THE INVENTION

The principles and operation of the method and system for steering a guided
10 flying object (e.g., projectile or missile) according to the invention may be better understood with reference to the drawings and the accompanying description, it being understood that these drawings are given for illustrative purposes only and are not meant to be limiting. The same reference numerals will be utilized for identifying those components which are common in the system and its parts shown
15 in the drawings throughout the present description of the invention.

Referring to **Fig. 1** and **Fig. 2** together, a perspective view of a guided projectile and a longitudinal cross-sectional view of a forward portion of the guided projectile are illustrated, in accordance with an embodiment of the present invention. It should be noted that these figures as well as further figure are not to
20 scale, and are not in proportion, for purposes of clarity.

The guided projectile **10** includes a forward portion **11** and a tail portion **12** mounted at the aft end of the forward portion **11**. A steering system **100** of the projectile is arranged in the forward portion **11** and includes an outer housing **111**, an inner housing **113**, and a plurality of support fins **112** extending radially
25 inwardly from the outer housing **111** and holding the inner housing **113** thereon. The outer housing **111** and the inner housing **113** define a ram air inlet **114** at a nose of the forward portion **11**, an annular inlet air passage **115** downstream of the ram air inlet **114**, an annular pressure chamber **116** downstream of the inlet air passage **115**, and an outlet air passage **125** at the aft end of the pressure chamber **116**

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between an inside wall 117 of outer housing 111 and an outside wall 118 of the inner housing 113. Preferably, but not mandatory, the support fins 112 extends forwardly through the ram air inlet 114. Such a feature can partially reduce stability margin of the projectile 10, and thereby provide more sensitivity to lateral thrust steering.

The tail portion 12 includes an explosive unit (not shown) and a plurality of stabilizing fins 131 fixed circumferentially around a cylindrical body 132 of the tail portion. In the embodiment shown, 6 equally spaced fins are employed.

In operation, incoming ram air RA enters the ram air inlet 114 of the traveling guided projectile 10, flows through the inlet air passage 115, the pressure chamber 116, then passes through the outlet air passage 125 and finally through a plurality of exhaust outlets 120 arranged in the outer housing 111. Preferably, the orientation of the exhaust outlets 120 is such so that an escaping air EA could produce thrust vectors having small or negligible forward motion components. The interaction between lateral thrust, thus created, and external flow provides asymmetric aerodynamic moments utilized for guiding the projectile. In the embodiment shown, four equally spaced exhaust outlets 120 are employed.

According to one embodiment of the invention, the inner housing 113 houses a target seeker 121, a control unit (system) 122 and an electrical power source module 123. The electrical power source module 123 can, for example, include a battery or an electric generator activated from the ram air for providing electrical power to the units of the projectile 10. It should be understood that electrical power source module 123 can also be mounted in any place within the forward portion 11 of the guided projectile 10.

The target seeker 121 is mounted at a nose of the projectile 10, and is configured for sensing a target (not shown) and producing a target sensor signal required for homing in at the target. For example, the signal can be representative of the location of the target. The control unit 122 is electrically coupled to the target seeker 121 and responsive to the target sensor signal for steering the projectile in order to correct its trajectory when the projectile is in flight. Examples of the target

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seeker **121** include, but are not limited to, TV seeker, IR seeker, laser seeker and radar seeker, configured for optical or electromagnetic observation of the target.

The steering system **100** further includes a plurality of separately controlled valves **124**. A number of the valves **124** corresponds to the number of the exhaust outlets **120**. Each valve is mounted at the corresponding exhaust outlet **120**. The valves **124** are electrically coupled to the control unit **122** and controllable in such a manner that they are able to vary the flow of the escaping air through the exhaust outlets **120**, and thus control the trajectory of the projectile. An example of the valve **124** includes, but is not limited to, a solenoid activation valve, known *per se*.

In operation, when no steering correction is required, the valves **124** are normally held in a position which closes the exhaust outlets **120**. As the projectile is in flight within atmosphere, a positive gauge ram air pressure (with respect to the atmospheric pressure) is present in the pressure chamber **116**. The valves **124**, when energized, open the exhaust outlets **120**, thereby allowing the air to escape therefrom.

Referring to **Figs. 2** and **3** together, the steering system **100** further comprises one or more pressure sensors mounted in the pressure chamber **116** and configured for measuring the gas pressure in the pressure chamber **116**. Preferably, the measuring of the gas pressure is carried out by utilizing a pressure sensor in cooperation with one or more controllable valves distant therefrom.

For example, two pressure sensors **119a** and **119b** can be employed in the system with four controllable valves **124a-124d**, as shown in **Fig. 3**. According to this example, when the controllable valves **124a** and/or **124b** operate, the measurement data of the pressure sensor **119b** located between the opposite controllable valves **124c** and/or **124d** can be used, and *vice versa*, the controllable valves **124c** and/or **124d** can operate in cooperation with the pressure sensor **119a**. This feature may provide more adaptive thrust control.

The pressure sensor(s) are configured for generating a pressure sensor signal representative of changes of gas pressure in the pressure chamber **116**. The control

unit 122 is electrically coupled to the pressure sensor(s) and responsive to the pressure sensor signal.

On the basis of the target sensor signal and the pressure sensor signal, the controller is able to generate a valve control signal, thereby to regulate the operation of the valves 124.

According to one embodiment, the valves 124 can operate in a sequential manner. In this case, only one valve is open at a certain time interval, while all other valves remain closed at this time interval. When required, the valves can operate in either a continuous regime or a pulse regime. In the continuous regime a valve is continuously open over the certain time interval, while in the pulse regime the valve opens and closes many times over this time interval.

According to another embodiment, the valves 124 can operate also in a parallel manner, i.e., when two or more valves can be open simultaneously.

As such, those skilled in the art to which the present invention pertains, can appreciate that while the present invention has been described in terms of preferred embodiments, the concept upon which this disclosure is based may readily be utilized as a basis for the designing of other devices and processes for carrying out the several purposes of the present invention.

Although the system and method for the steering of a traveling guided projectile have been described hereabove in the detail description section, it should be understood that these method and system can be used for the steering of a missile, rocket, bomb and/or any other similar flying apparatus, *mutatis mutandis*.

Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

It is important, therefore, that the scope of the invention is not construed as being limited by the illustrative embodiments set forth herein. Other variations are possible within the scope of the present invention as defined in the appended claims and their equivalents.

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CLAIMS:

1. A steering system for use in a traveling guided flying apparatus, the system comprising:

5 an outer housing and an inner housing defining: a ram air inlet at a nose of the forward portion, an annular inlet air passage, an annular pressure chamber, and outlet air passage between an inside wall of the outer housing and an outside wall of the inner housing;

a plurality of support fins extending radially inwardly from the outer housing and holding the inner housing thereon;

10 a plurality of exhaust outlets arranged in the outer housing;

a plurality of separately controlled valves mounted at the exhaust outlets; the valves being configured to vary the flow of escaping air through the exhaust outlets;

15 a target seeker mounted at the nose of the forward portion and configured for sensing a target and producing a target sensor signal representative of the relative location of the target;

at least one pressure sensor mounted in the pressure chamber and configured for measuring the gas pressure therein and producing a pressure sensor signal representative of changes of gas pressure in the pressure chamber;

20 a control unit mounted within the flying apparatus and operatively coupled to the controlled valves, the target seeker, and the pressure sensor, said control unit being responsive to said target sensor signal and said pressure sensor signal, and configured for controlling flight of the guided projectile by generating a valve control signal and providing said valve control signal to said plurality of separately controlled valves; and

25 an electrical power source module mounted within the flying apparatus and operable to provide electrical power required for operating said target seeker, said at least one pressure sensor, and said plurality of separately controlled valves.

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2. The system of claim 1 wherein said flying apparatus is selected from a projectile, missile, rocket and bomb.
3. The system of claim 1 wherein orientation of the exhaust outlets is such so that an escaping air could produce thrust vectors having small or negligible forward motion components.
4. The system of any one of the preceding claims wherein said the support fins extends forwardly through the ram air inlet.
5. The system of any one of the preceding claims comprising:
a first controllable valve;
a second controllable valve;
a third controllable valve;
a fourth controllable valve;
a first pressure sensor arranged between said first controllable valve and said second controllable valve; and
a second pressure sensor arranged between said third controllable valve and said fourth controllable valve;
wherein said first pressure sensor operates in cooperation with any one of the third and said fourth controllable valves; and said second pressure sensor operates in cooperation with any one of the first and said second controllable valves.
6. A method for driving the steering system of any one of the preceding claims, comprising:
receiving ram air by the ram air inlet;
directing said ram air through the air passage to the pressure chamber;
controllably releasing said ram air from the pressure chamber through said plurality of separately controlled valves arranged downstream of the pressure

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chamber by controllable operating said controlled valves, wherein said controllable operating includes:

sensing the target and producing said target sensor signal required for homing in at the target;

5 measuring the gas pressure the pressure chamber and producing a pressure sensor signal representative of changes of gas pressure in therein; and

generating a valve control signal and providing said valve control signal to said plurality of separately controlled valves in response to said target sensor signal and said pressure sensor signal,
10 thereby controlling flight of the guided flying apparatus.

7. The method of claim 6 wherein said measuring of the gas pressure includes utilizing a pressure sensor in cooperation with at least one controllable valve distant
15 therefrom.

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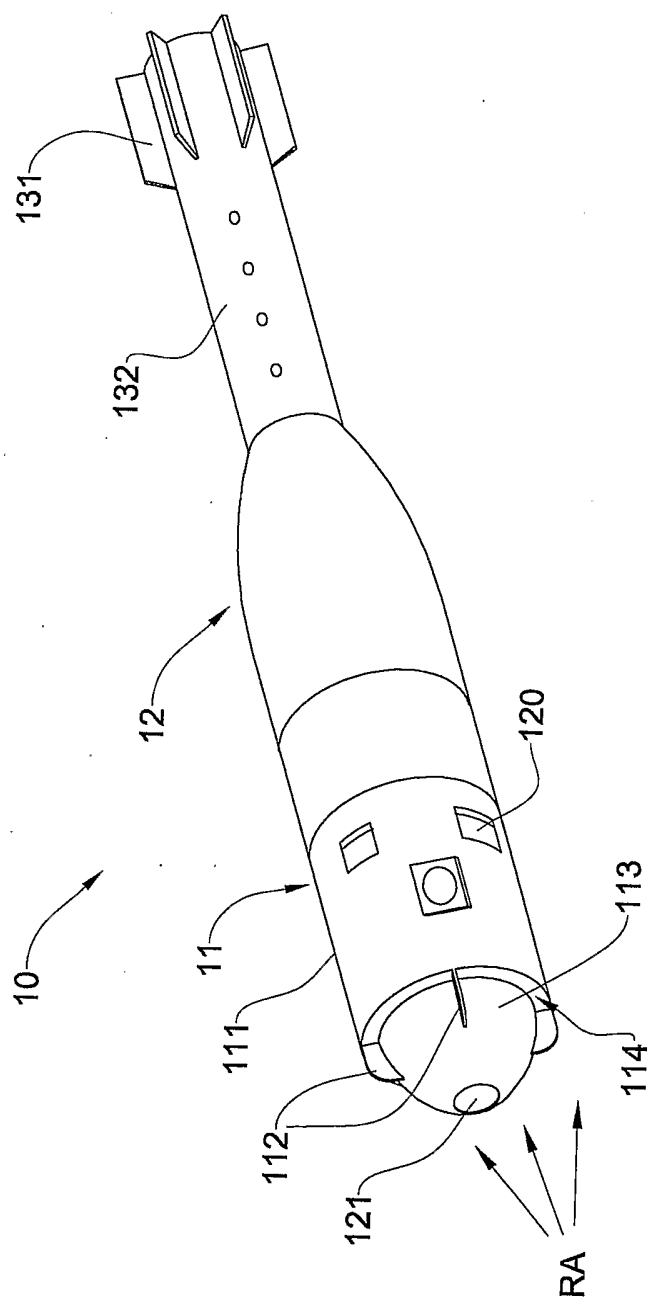


FIG. 1

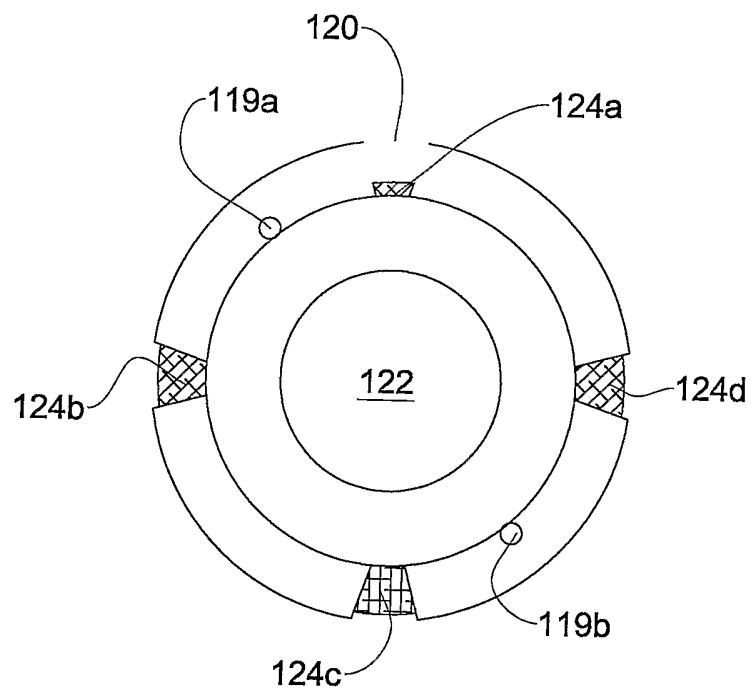


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No

PCT/IL2006/000108

A. CLASSIFICATION OF SUBJECT MATTER
INV. F42B10/66

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

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 practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 537 371 A (LAWHORN ET AL) 27 August 1985 (1985-08-27) column 3, line 20 - column 5, line 23 figures	1-7
A	US 3 977 629 A (TUBEUF ET AL) 31 August 1976 (1976-08-31) the whole document	1-7
A	US 3 819 117 A (MOORHEAD S,US) 25 June 1974 (1974-06-25) the whole document	
A	DE 42 32 738 A1 (RHEINMETALL GMBH, 40882 RATINGEN, DE) 31 March 1994 (1994-03-31) the whole document	
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Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
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Date of the actual completion of the international search

18 May 2006

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29/05/2006

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Gex-Collet, A-L

INTERNATIONAL SEARCH REPORT

International application No

PCT/IL2006/000108

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 706 650 A (THAYER ET AL) 13 January 1998 (1998-01-13) the whole document -----	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IL2006/000108

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 3977629	A	31-08-1976	DE 2444920 A1 17-04-1975 FR 2244978 A1 18-04-1975 IT 1024554 B 20-07-1978 JP 50060000 A 23-05-1975
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US 5706650	A	13-01-1998	NONE