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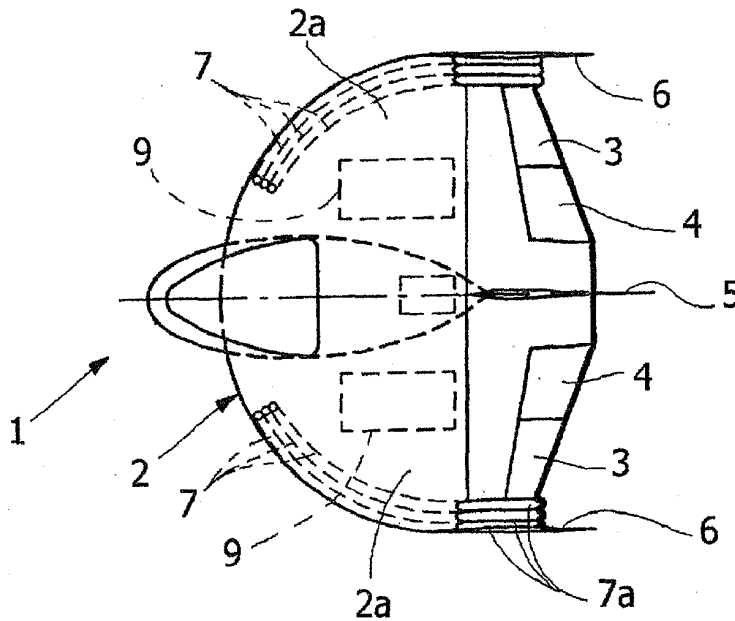
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(54) **Aircraft, particularly small aircraft, having a propulsion system including a plurality of pulse detonation engines (PDEs)**

(57) A small aircraft is disclosed having a propulsion system including a plurality of Pulse Detonation Engines (PDEs). The engines are arranged within the wings (2a) of the aircraft. The discharge nozzles (8) of the detonation tubes (7) of the detonation engines are provided at

different areas of the aircraft and are differently oriented, so as to provide extra manoeuvrability along the three directions. The arrangement of the detonation tubes (7) within the wings (2a) reduces drag and hence the fuel consumption.

**FIG. 3**



## Description

**[0001]** The present invention is referred in general to the aircraft technique and in particular to small aircrafts, either of the manned or unmanned type, provided with a propulsion system including a plurality of Pulse Detonation Engines.

**[0002]** Since the 1940s, a research has been developed for application of the detonation regime of combustion in various fields. The advantage of a combustion under a detonation regime over classical combustion is the high rate of the energy release. It allows designing of the propulsion engines with a very high power density. In Pulse Detonation Devices (PDDs) a constant volume, thermodynamic cycle is effectively realized.

**[0003]** The most interesting development of the PDDs is constituted by the Pulse Detonation Engines (PDEs). The advantages of PDEs over conventional propulsion engines (turbo, ramjet, piston engines) are engine efficiency, simplicity of construction, small dimensions and reduced weight and capability to work efficiently both at low and supersonic speeds. PDEs have been disclosed for instance by Nicholls J.A., Wilkinson H.R., Morrison R.B. (1957), in "Intermittent detonation as a thrust-producing mechanism", *Jet Propulsion* 27 (5): 534-41, and by Eidelman S., Grossman W. (1992) in "Pulsed detonation engine, Experimental and theoretical Review, AIAA paper 92-3168.

**[0004]** The basic PDE set-up is a simple detonation tube open at one end (see also Wilson D.R., Lu F.K., Stuessy W.S. (1999) "Gaseous detonation phenomena with shock and arc initiation", I.; *Proc. 21<sup>st</sup> Int Symp Shock Waves* 421-425). At the closed end of the tube there are fuel and oxygen injectors. After filling the detonation chamber by a detonable mixture, the detonation can be initiated in two different positions: at the open or the closed end. In any case, the pushing of the detonation products on the closed end (the thrust wall) produces the thrust.

**[0005]** The application of PDEs to the propulsion of aircrafts is known for example from document RU 2130407, published on 20.05.1999.

**[0006]** The object of the present invention is that of providing an aircraft, particularly a small aircraft, either of the manned or unmanned type, which is to flight with a relatively reduced load and at relatively low speeds, using the combustion under detonation regime with a high efficiency and particularly with a very reduced fuel consumption.

**[0007]** A further object of the invention is that of providing an aircraft which has the ability of combining two regimes of flight: vertical, or sub-vertical, take-off and landing and cruising regime.

**[0008]** Yet another object of the invention is that of providing an aircraft of the above indicated type with a high flight stability and high manoeuvrability.

**[0009]** In view of achieving these and further objects, the aircraft according to the invention has the features

indicated in the annexed claim 1.

**[0010]** Further preferred features of the aircraft according to the invention are indicated in the dependent claims.

5 **[0011]** An essential feature of the aircraft according to the invention lies in that it is provided with groups of PDEs formed by detonation tubes which are arranged within the wings of the aircraft. To this end, the detonation tubes provided on the aircraft preferably have a curved configuration, so that they can follow a curved or inclined profile of the wing leading edge, when viewed from above.

10 **[0012]** A further basic feature of the invention lies in that the various detonation tubes provided on the aircraft can be controlled independently from each other or in groups, and therefore can be actuated selectively, so that the value of the thrust can be controlled. The ability of fine-tuning of the thrust also gives an opportunity to obtain extra stability and manoeuvrability of the aircraft especially at vertical or sub-vertical take-off/landing and at transition to cruising regime.

15 **[0013]** A further important feature of the invention lies in that the nozzles of the various detonation tubes are oriented in different directions so that they can be used selectively at the various flight regimes, and particularly in vertical or sub-vertical take-off/landing and at cruising regime.

20 **[0014]** The arrangement of the detonation tubes within the wings of the aircraft produces a lower fuel consumption by virtue of the reduction of the aerodynamic drag. The propulsion system does not have an exposed cross-section area, since it is located within the wings. As a result, the value of front thrust, intended as the ratio of the thrust to the value of maximum exposed engine cross-section area in this case is extremely high.

25 **[0015]** A further important feature of invention lies in that the nozzles of the various detonation tubes are offset with respect to each other. The spacing of the detonation tubes from each other along the horizontal direction and the vertical direction and the offset of the nozzles relative to each other along the longitudinal direction of the tubes are selected at design stage to obtain a minimum level of noise by exploiting the interference of acoustic waves caused by the detonations. Further parameters which can be determined to this end are the diameter of the tubes, which may also be different for different tubes, as well as the angles which the longitudinal direction of each nozzle defines with respect to a reference system.

30 **[0016]** Further features and advantages of the invention will become apparent from the description which follows with reference to the annexed drawings, given purely by way of non limiting example, in which:

35 55 figures 1, 2 and 3 show an elevational side view, a front view and a plan view of one embodiment of an aircraft according to the invention, figure 4 is a diagrammatic view of a plurality of det-

onation tubes provided in the aircraft of figures 1-3, figure 5 is an end view of the assembly of figure 4, and, figure 6 shows the detail of one end portion of a detonation tube.

**[0017]** The annexed drawings show an example of the application of invention to a small aircraft having an "all-wing" configuration. In a real embodiment, this aircraft may have a wing span around 3 m and a wing surface around 8 m<sup>2</sup>. The aircraft can be designed for piloted transportation or as an unmanned aircraft, for transportation of small loads. In the shown configuration, the aircraft comprises a fuselage 1 and a wing structure 2 formed by two wings 2a which in the illustrated embodiment have a leading edge having, when viewed from above, a profile substantially in form of an arch of a circle. At its trailing edge, the wing 2 is provided both with ailerons 3 and with horizontal tail surfaces 4. A vertical tail surface 5 is further provided with an associated movable rudder, along with two vertical surfaces 6 at the ends of the wings 2a.

**[0018]** As diagrammatically shown in the drawings, within the two wings 2a there are arranged two groups of PDEs 7 which in the illustrated example have a curved configuration so as to follow the curved configuration, viewed from above, of the leading edge of the wing 2. Each PDE is constituted by a detonation tube having a terminal portion 7a arranged outside of the aircraft body, with an end nozzle 8 (figure 4).

**[0019]** Figure 4 shows, for sake of simplicity, a plurality of detonation tubes 7 arranged on the aircraft according to the invention, as being straight and parallel. However, in the real embodiment, each detonation tube 7 may be curved and may have an end portion forming the nozzle 8 which on its turn may be curved (see figure 6) or in any case can be directed along a direction which can be different from that of the other nozzles.

**[0020]** The annexed drawings do not show the details of the structure of each detonation tube, the injectors for the fuel and the oxygen or air which are associated thereto, as well as the means for controlling these injectors and the means for initiating the detonation combustion within the detonation chamber defined by each tube. All the above mentioned details of construction can be made in any known way, and do not fall, taken alone, within the scope of the present invention. On the other hand, the deletion of these details from the drawings renders the latter simpler and easier to understand.

**[0021]** As already indicated in the foregoing, the various detonation tubes which are provided on the aircraft have their nozzles directed along different directions and are controlled independently from each other, or in groups, in a selective manner, to adjust the amount of the thrust, as well as to obtain the desired components of the thrust along the horizontal and vertical directions in the various flight regimes (vertical and sub-vertical take-off/landing, cruising regime) and for having extra

stability and manoeuvrability, particularly in flight at low speeds.

**[0022]** As also indicated in the foregoing, at design stage, the diameter  $d$  (figure 5) of each tube, the distance  $d_h$  between adjacent tubes along the horizontal direction, and the distance  $d_v$  along the vertical direction are selected also in order to obtain a minimum level of noise by exploiting the interference between the acoustic waves caused by the detonations within the tubes. Under this respect, it is particularly important that the nozzles 8 are arranged at positions offset along the longitudinal direction of the tubes relative to each other, the amount  $p$  of this offset (figure 4) being also selected as a function of the noise reduction features which are desired. The direction of each nozzle 8 is identified by the angles formed by the longitudinal axis of the nozzles 8 with respect to a reference system and also these angles can be varied at design stage in order to obtain the required characteristics. Also the positioning of the tubes at different areas of the aircraft and above all the provision of the nozzles of the tubes at different areas of the aircraft give the possibility of providing an aircraft with high efficiency and stability.

**[0023]** In the case of the specific embodiment shown, two further propulsion engines 9 can be provided, of conventional type, for example two propeller engines, for the cruising regime.

**[0024]** In a real embodiment, the two groups of detonation tubes 7 provided in the wings may have about 30-50 tubes each, for example 40 tubes, having a diameter of about 1-1.5 cm and a length of about 150-300 cm.

**[0025]** According to a further feature, the tubes are preferably made of carbon, both for reduction of weight and for a better heat dissipation.

**[0026]** A further preferred feature lies in the provision of one or more air compressors for compressing air to the value of pressure required before feeding this air to the detonation tubes.

**[0027]** Naturally, while the principle of the invention remains the same, the details of construction and the embodiments may widely vary with respect to what has been described and shown purely by way of example, without departing from the scope of invention.

## Claims

1. Aircraft, particularly a small aircraft, either of the manned or unmanned type, provided with a propulsion system including a plurality of Pulse Detonation Engines (PDEs) each comprising a detonation tube (7) with a close end, defining a detonation chamber, a nozzle (8) at the opposite end and means for feeding air or oxygen and a fuel within the detonation chamber for initiating a combustion under detonation regime within said chamber, characterized in that said detonation tubes (7) are arranged within the wings (2a) of the aircraft

for at least a prevailing portion of their length.

2. Aircraft according to claim 1, **characterized in that** the detonation tubes (7) have a curved configuration which follows a curved or inclined configuration of the leading edge of the wings (2a), when viewed from above. 5
3. Aircraft according to claim 1, **characterized in that** there are provided means for controlling the operation of said detonation tubes (7) or of groups of said detonation tubes (7), independently from each other, so that it possible in particular to select the tubes which are active to adjust the amount of thrust in order to obtain extra capability of controlling the aircraft. 10 15
4. Aircraft according to any of the previous claims, **characterized in that** the nozzles (8) of the detonation tube (7) are oriented along different directions to provide a capability of flight under different regimes, including a vertical or sub-vertical take-off/landing regime and a cruising regime. 20
5. Aircraft according to any of the previous claims, **characterized in that** the nozzles (8) of the detonation tube (7) are off-set with respect to each other along the longitudinal direction of the tubes. 25
6. Aircraft according to claim 5, **characterized in that** one or more parameters chosen from: amount (p) of the longitudinal offset of the nozzles (8), diameter (d) of the detonation tubes (7), horizontal spacing ( $d_h$ ) between adjacent tubes, vertical spacing ( $d_v$ ) between adjacent tubes, are predetermined in order to minimize the level of noise by exploiting the interference of the acoustic waves caused by the detonation within the tubes (7). 30 35
7. Aircraft according to any of the previous claims, **characterized in that** it has a wing span in the order of a few meters. 40
8. Aircraft according to claim 7, **characterized in that** each wing (2a) of the aircraft is provided with a few tens of detonation tubes. 45
9. Aircraft according to claim 7, **characterized in that** each tube has a length in the order of 150-300 cm and a diameter in the order of 1-1,5 cm. 50
10. Aircraft according to claim 1, **characterized in that** it has a wing surface in the order of a few square meters. 55
11. Aircraft according to claim 1, **characterized in that** the means for feeding air or oxygen are able to inject air or oxygen under pressure.
12. Aircraft according to claim 11, **characterized in that** at least one compressor is provided on the aircraft for compressing the air to be fed to the detonation tubes (7) up to the required value of pressure.

FIG. 1

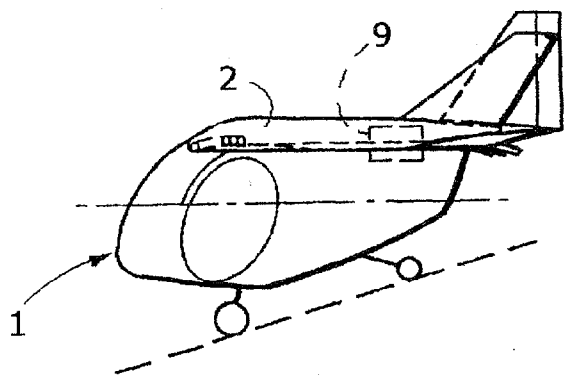


FIG. 2

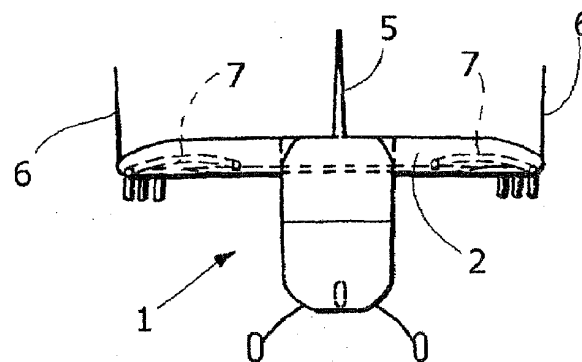


FIG. 3

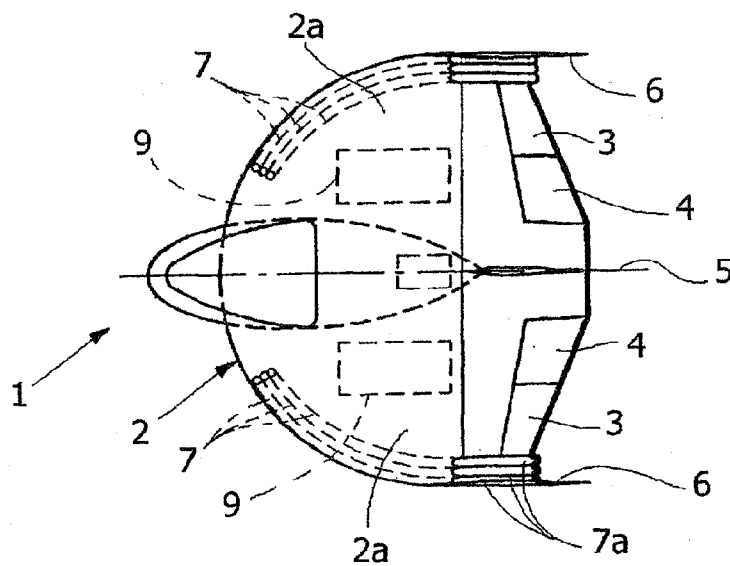


FIG. 4

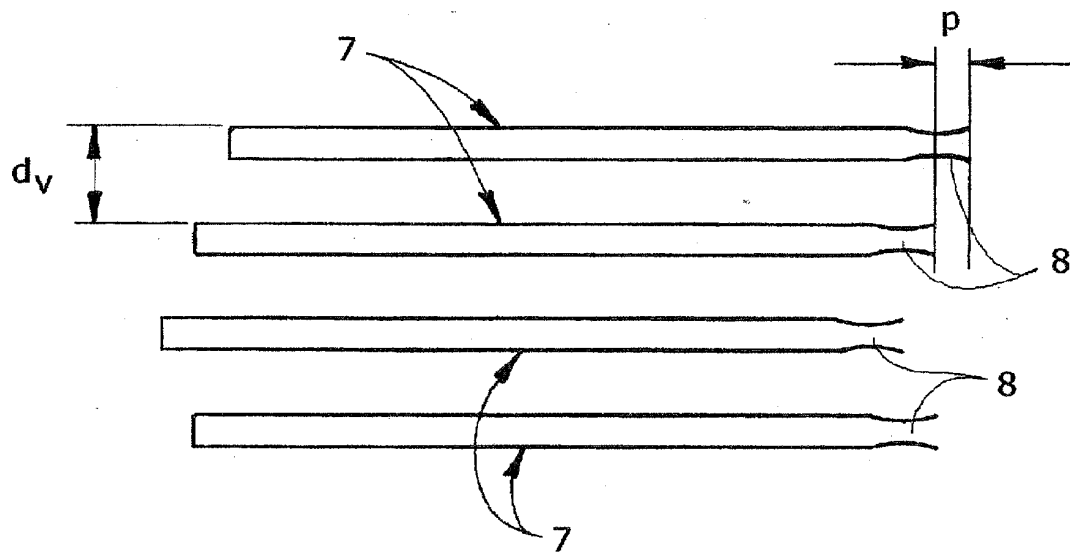


FIG. 5

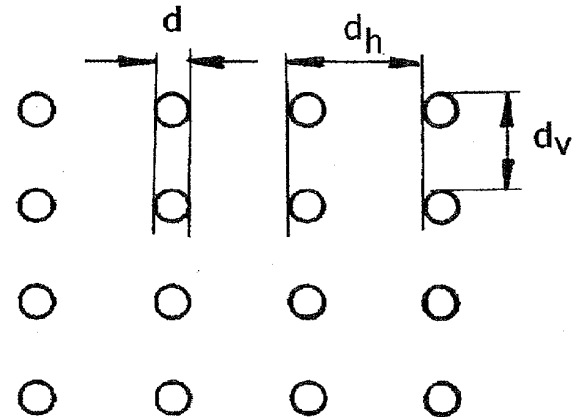
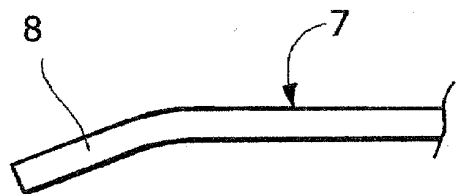


FIG. 6





European Patent  
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EUROPEAN SEARCH REPORT

Application Number  
EP 04 42 5043

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X,D	RU 2 130 407 C (ANAKIN ANATOLIJ TIMOFEEVICH;BLIZNJUK VALENTIN IVANOVICH; IGNATOV ALEKS) 20 May 1999 (1999-05-20) * abstract; figures *	1,4,8, 11,12	B64D27/02 F02K7/075 B64D27/18
Y	---	2	
Y	US 2 972 862 A (PIERRE SERVANTY) 28 February 1961 (1961-02-28) * the whole document *	2	
A	US 2 756 008 A (MACAULAY DAVIDSON IVOR) 24 July 1956 (1956-07-24) * figures * * column 1, line 51 - column 2, line 39 *	1-12	
A	FR 2 166 324 A (GUILLON MARCEL) 17 August 1973 (1973-08-17) * the whole document *	1-12	
A	US 2 377 247 A (ERNEST LAGELBAUER) 29 May 1945 (1945-05-29) * page 2, line 45 - page 3, line 66 *	1-12	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	GB 2 383 823 A (BIRKETT HAROLD) 9 July 2003 (2003-07-09) * the whole document *	1-12	F02K B64D
The present search report has been drawn up for all claims			
Place of search <b>MUNICH</b>		Date of completion of the search <b>2 July 2004</b>	Examiner <b>Teissier, D</b>
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 04 42 5043

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02-07-2004

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
RU 2130407	C	20-05-1999	RU 2130407 C1	20-05-1999
US 2972862	A	28-02-1961	NONE	
US 2756008	A	24-07-1956	CH 317117 A	15-11-1956
			CH 319785 A	28-02-1957
			CH 326061 A	30-11-1957
			CH 326233 A	15-12-1957
			DE 1021249 B	19-12-1957
			FR 1099647 A	07-09-1955
			NL 91484 C	
FR 2166324	A	17-08-1973	FR 2166324 A1	17-08-1973
US 2377247	A	29-05-1945	NONE	
GB 2383823	A	09-07-2003	NONE	