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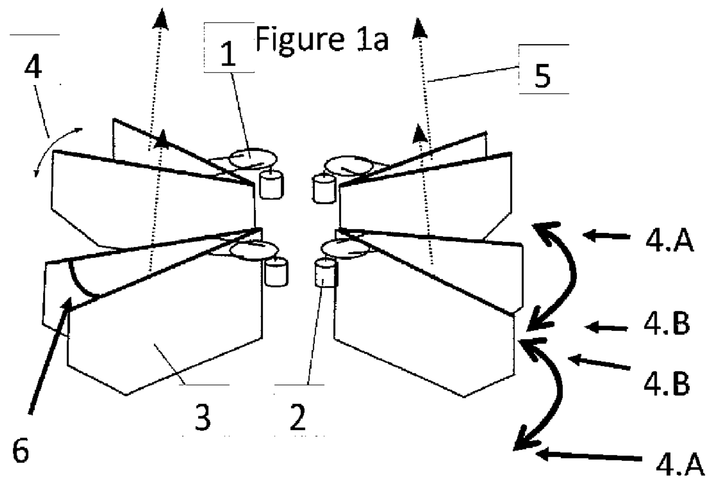
(54) Title: MULTIPLE PAIRS OF FLAPPING WINGS FOR ATTITUDE CONTROL



(57) Abstract: Wing arrangement (3,WPA) for a mini flapping wing flying device, comprising a first and a second wing which are pivotal relative to each other, wherein both wings comprise a wing area (19), and a leading edge (18); wherein driving means (2) provide movement of both wings relative to each other, each leading edge being rigid and each wing area resilient, wherein both wings can be in a first position (4B), wherein both leading edges and wing areas are close, and a second position (4A) wherein both leading edges and wing areas are positioned at a larger angle and form a V-shape; and wherein both wings are movable between the first and second position in anti-phase. Each wing arrangement can extend outwards at a side of the device and provide an independent thrust vector, whereby a controller can adapt said vector in size and optionally in direction.

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Multiple pairs of flapping wings for attitude control

FIELD OF THE INVENTION

The present invention is in the field of micro air vehicles having flapping wings.

BACKGROUND OF THE INVENTION

The present invention is in the field of micro air vehicles (MAVs) having flapping wings, which combines a multicopter technology and a flapping micro air vehicle in one device.

An MAV commonly known as drone relates to a powered aerial vehicle that does not carry a human operator and uses aerodynamic forces to provide vehicle lift. MAVs can fly autonomously by computers and by piloted remotely.

MAVs are used in several applications, such as for intelligence, in military and non-military security work, and in toy industry. MAVs can fly outdoors, or enter a doorway to investigate indoor environments.

Three types of MAVs exist, fixed wing (airplane type), rotatory wing (helicopter type) and flapping wing vehicles (ornithopters). These are more attractive compared to the other two types. Although fixed wing MAVs have a high efficiency and a long flight, they cannot hover. Rotary wings on the other hand can hover but have a shorter flight. A multicopter is a type of rotary wing craft with more than two rotors. In this respect, the term "oligocopter" may be a better term. Multicopters can achieve stable hovering by balancing the forces produced by the multiple number of rotors.

Flapping wings offer potential advantages in manoeuvrability and energy saving. They have a combined function of providing both lift and thrust simultaneously by twisting the wings throughout the flapping stoke. Lift is the force that keeps the MAV airborne, and thrust is the force that propels the MAV forward.

Especially for the smaller vehicles, flapping wings are interesting, if and only if they have sufficient attitude control. Especially in confined areas, such as small indoor areas, there is a problem with manoeuvrability and tight radius turns of MAVs, due to lack of attitude control.

Attitude control is controlling the orientation of the vehicle with respect to its centre of mass. Attitude control in flight dynamics is defined by three critical flight dynamics parameters, known as "roll", "pitch" and "yaw". Roll is rotation of the vehicle around the longitudinal axis (such as front-to-back) (figure 3, 16), pitch is rotation around the lateral axis (such as wingtip-to-wingtip) (figure 3, 17), and yaw is rotation around the vertical axis (such as top-to-bottom) (figure 3, 15).

Various flapping wing MAVs are on the market. An example thereof is a tailed MAV. Tailed MAVs have stabilizing aerodynamic horizontal and vertical tail sections, typically with control surfaces or propellers to make the vehicle stable. A problem with tailed MAVs is their non-linear behaviour due to changing flow over the tail. For instance, when a MAV descends, the airflow over the tail reverses (parallel to a flight orientation) which means that in that regime, there is improper attitude control.

Another class of MAVs relates to tailless vehicles. Tailless MAVs have more potential to be more manoeuvrable compared e.g. to the tailed MAVs. However, they use heavy and complex mechanical systems to change forces on the wing during a flapping motion. This typically heavy mechanism is driven by actuators, which must be fast, strong and light. This combination is very difficult and typically, only two of the three are met: they are either fast and light but weak, or strong and fast but heavy, or fast and light but not strong. Solutions that meet all three relatively well are extremely expensive. This directly means that the vehicle is not well controllable or extremely heavy.

In addition to the above problems, when two opposing wings do not flap in phase and/or may have a different frequency (rpm), unwanted vibrations occur. This causes further instabilities.

Some documents recite micro air vehicles.

KR 2015 0079099 A recites a flapping flying object and the flapping flying object including multiple wing portions which are respectively flapped being arranged along the longitudinal direction arranged of the body which are rotatably combined in the body around a cross axis wherein a first wing and a second wing intersect at a predetermined length. It seems that without the tail-section no full control is possible. However no independent adapting thrust vectors of the wing arrangements is possible. For instance, the flying object can not hover. In fact the left and right wings are paired and connected to one and another; hence a wing pair extends at both sides. In addition it is not clear if the wings move in anti-phase.

US 2013/320133 A1 recites Multi-wing hovering and gliding flapping Micro Air Vehicles ("MAV") are disclosed. The MAV can have independent wing control to provide enhanced energy efficiency and high maneuverability. Power to each wing can be controlled separately by varying the amplitude and/or frequency of the wing flapping. The wings can be transitioned between flapping flight and fixed wing flight to enable gliding and hovering in a single configuration. The document however does not recite pairs of wings, and certainly not pairs of wings moving in anti-phase.

US 2005/269447 A1 recites a more effective method of ornithopter flight control. The ornithopter has controlled drive systems for flapping the two wings independently of each other. Various wing movements cause the ornithopter maneuver. Weight and complexity are reduced. Only one left and one right wing are disclosed, certainly not pairs of wings.

DE 20 2007 018524 U1 recites a flapping wing assembly, particularly for use in an aircraft or for moving a fluid with one or more reciprocating flapping wings and a thereto coupled restoring force device which is configured to set a deflection of flapping wings of at least one assigned starting position a restoring force against, characterized in that said back and stimulated reciprocating movement by a controllable drive, is maintained or slowed down in the bore and to or during the introduction of drive energy via at least one sensory device on the resulting amplitude, the current position or the frequency of the vane vibration is closed and serves the information provided by these sensory means, the energy content, the effective direction or the evolution of this or a following impulse, by means of a control to influence so that the resulting amplitude or frequency of wing vibration approaches a predetermined by the control value. At the most four wings are disclosed, which relate therefore to two pairs at the best.

CN 104 015 828 A recites a bionic wing-flapping and bouncing multi-mode movement robot which comprises a rack, a bouncing mechanism, a wing-flapping mechanism and a driving mechanism, wherein the bouncing mechanism, the wing-flapping mechanism and the driving mechanism are arranged on the rack. The wing-flapping mechanism comprises no more than two wing mechanisms and two tail wing mechanisms, wherein the two wing mechanisms and the two tail wing mechanisms are respectively symmetrical in a left-right mode. The driving mechanism with the single motor drives the wing mechanisms. At the most four wings are disclosed, which relate therefore to two pairs at the best.

The present invention therefore relates to an apparatus for flying with sophisticated attitude control, which solves one or more of the above problems and drawbacks of the prior art, providing reliable results, without jeopardizing functionality and advantages.

SUMMARY OF THE INVENTION

In a first aspect the present invention relates to a mini flapping wing device for flying according to claim 1.

According to the present invention there is provided a mini flapping device, which has an improved maneuverability, reduced complexity, reduced weight and increased strength, and is more efficient compared to the prior art concepts. The invention uses pairs of wings (also called "wing arrangement" (3) comprising a first and second wing). At least three wing arrangements can be used in this invention, in which preferably at least three equal driving mechanisms are attached on each wing arrangement. In case of three wing arrangements, yaw and roll are close-coupled, meaning that the aircraft cannot yaw without rolling and the aircraft cannot roll without yawing. This yaw-roll coupling can be used in toy industry, e.g. in drone racing competitions. In case of three wing arrangement, to obtain non-coupled yaw-roll an extra servomotor is required.

The present controller is for independently adapting thrust vectors of the wing arrangements. It is noted that in use, during flapping, thrust vectors may vary continuously, typically in size and optionally in direction. The thrust vectors can be adapted in size and optionally in direction. The size of the thrust vector can be changed by means of altering the flapping frequency of the wing arrangement. The direction for instance can be changed by either rotating the entire wing arrangement or by moving the trailing edge of the wing arrangement, which in turn alters the mean cord of the flapping wings. When flapping the leading edges of each wing arrangement can be considered to define a flapping plane; the thrust vector 5 is typically "located" at a "central" position of the flapping plane. The average thrust vector is often close to perpendicular to the flapping plane but may vary with to total vehicle motion and the deformation of the mean wing cord. Note that the above passage is a simplification, in that e.g. wind may complicate the picture. By having wing arrangement extending outwards of a side of the present device, a set of independent thrust vectors is provided of which none go through the below centre of gravity. In a hovering mode no movement of the device is provided; the sum of the thrust vectors compensate a gravitational force exactly; the sum of the thrust vectors then go through a virtual centre of gravity. When in motion a line from tip to tail may define a longitudinal axis, which typically runs through the centre of gravity. Wing arrangements are located such that each arrangement can have a thrust vector independently of one and another, which thrust vector can be adapted. Each wing arrangement in a closed position may independently extend in any direction, such as perpendicular to the longitudinal axis, and also under another angle with respect to said axis. Thrust vectors are typically provided at a distance of the centre of gravity, and typically also at a distance of the longitudinal axis; such follows inherently from independently adapting thrust vectors in combination with full attitude control; as such at least two, and typically all, wing arrangements are located at a distance from the longitudinal axis. Phrase differently; thrust vectors are not in line. In an example a thrust vector of a right wing arrangement may be adapted in combination with one of a left wing arrangement, such that with respect to the centre of gravity both are adapted symmetrically. In an example (of three wing arrangement) only one (front or back) wing arrangement may be rotated. Therewith full and very quick attitude control is provided.

Each wing arrangement extends outwards at a side of the device; seen from above, a first pair of wings may for example extend at a left top side of the device, a second pair at a left bottom side, and similar two pairs at a right side. Or a pair may extend at a front side, and two pairs may extend at a right and left bottom side, respectively. Typically each wing arrangement extends in an independent and different direction from any other wing arrangement, to be capable of providing an independent thrust vector.

Each of the thrust vectors (see fig.1, 5), (adjusted by wing arrangements), is independently controllable to allow full attitude control. In addition, less vibration is achieved due to use of wing arrangements. In fact high-speed high-resolution recordings did not show any problematic vibration. A mini flapping wing device relates to a flapping flight vehicle which is less than 200 cm in size. The size is the largest cross sectional dimension. The present vehicles could be as small as 0.1 mm size, but typically are 1-15 cm in size, such as 2-10 cm, e.g. 25 mm.

The flapping motion in the present invention may use a traditional crank rocker flapping mechanism (1), which consists of a fixed link, a crank, and a rocker. In the crank rocker flapping mechanism, the rocker, which is connected to the fixed link, oscillates, while the crank can fully rotate (360 degree). The rocker crank mechanism provides a way to transform the 360-degree rotation of the motor shaft (which drives the crank) to a flapping motion (by connecting the wing to the rocker). The rocker is driven by a driver 2. In other words, the crank rocker flapping mechanism converts rotational motion to translational motions. A controller is connected to each drive engine, and it controls the driving means.

One cycle in the flight of a flapping wing vehicle consists of a down stroke and an upstroke, which produce both thrust and lift components of the aerodynamic force.

The flapping wings may be in a more horizontal configuration (trailing edge to leading edge vector points forward) during a horizontal flight mode, and in a vertical configuration (trailing edge to leading edge vector points upward) for a hover mode. In addition the flapping wings may be slightly tilted, such as to provide yaw.

During fast forward flight, the lift (for staying in the air) is typically not provided by the thrust anymore, such as in multicopters, but instead is provided by the airflow over the flapping wings; this results in much more efficient (estimated to attribute to 20-50% in terms of energy) forward flight.

The present flapping wings can also achieve 30% higher lift coefficients (=lift per unit of surface) than fixed wing craft as estimated.

A wing arrangement (3) is used to minimize vibrations by operating in phase while allowing independent force control. The wings can be thin, bendable and of any shape. Each wing comprise a wing area 19, and a leading edge 18(see fig. 1). The front of the wing is called leading edge. Each leading edge is rigid (e.g. having a flexural strength of > 50 MPa, preferably > 100 MPa (measured according to ASTM D790) and each wing area is resilient. Suitable materials for the leading edge are lightweight metals, such as aluminum, polymers, such as thermo-hardened polymers, epoxy comprising materials, and composites, such as an epoxy comprising carbon fibres, and combinations thereof. Suitable materials for the wing area are thin foils (1-100 μm) of elastomeric polymers. Both wings can be in a first position, wherein both leading edges and both wing areas are close to one and another, such as substantially parallel and adjoining (γ=0), (4.B), and a second position wherein both leading edges and both wing areas are positioned at a larger angle (γ e.g. $\in$[5,180]) and form a V-shape (4.A).

In order to keep the device flying, an electrical power source (14), such as a battery, is required. In an example approximately 1W is required for a device with four wing arrangements.

Thereby the present invention provides a solution to one or more of the above-mentioned problems.

Advantages of the present description are detailed throughout the description.

DETAILED DESCRIPTION OF THE INVENTION

In an exemplary embodiment of the present flapping wing device, at least one wing arrangement is rotatably mounted on the mini flapping wing device via a single pivot point 20 for both wings for attitude control, specifically yaw control. In other words, with respect to a fuselage at least one pair of wings is rotated, or two pairs of wings are rotated at a same time, etc. in view of an intended attitude control. A "tri-flapper" is an example of such a device, wherein one pair may rotate in order to provide yaw.

The present invention can have multiple wing arrangements, and each wing arrangements can flap independently. Flapping motion is regarded as a movement of wings, such as up and down or back and forth, i.e. a flight is bird like. In other words, when one wing of the pair moves one way, the other moves the other way at the same speed to balance the moments. The wings can be connected to a fuselage (7) (see fig. 1-2) of the mini flapping device through various mechanical points. A fuselage (6) is considered to be the main body of the aircraft. In principle, a fuselage (7) can be customized to accommodate any number of wing arrangements. A suitable stabilization electronics for the present device with four wing arrangements is for instance the same as for the CX10 multicopter of Cheerson; said multicopter provides a less preferred example of a fuselage to which the present wing arrangements could be attached, albeit with some further modifications.

A pivot point is regarded as an apparent virtual center of rotation of the flapping wing arrangement. In physical terms a pivot (and likewise pivot point)is considered to relate to a pin or shaft on which the wing arrangement can flap and optionally turn, i.e. rotate freely in all directions, in so far as not limited by other elements of the present device. In an example, the pivot point is an interface to attach two wings. The pivot points can be customized, for instance, two wings of a wing arrangement are mounted on the same plane, or one wing of a wing arrangement is shifted up with respect to the other wing of the wing arrangement, or there is a horizontal distance between first wing and the second wing.

Pitch and roll controls are done by changing thrust vectors to provide a difference between these vectors, e.g. from left and right, and front to back, respectively. In other words, more thrust to one wing arrangement and/or less thrust to its opposite wing arrangement can be applied. Yaw control can be obtained by mounting diagonally opposing wings at an angle (11, ±α) and increasing thrust from one diagonal compared to the other. Yaw control relates to changing the direction of which the flapping wing device is oriented. The present device can change direction, i.e. a 90-degree rotation, within a few hundred millisecond, and possibly within 50 msec. To adjust the thrust, an amplitude of a flapping motion of the wings can be adjusted (for a same frequency). For instance, to produce a higher thrust, the amplitude of the flapping motion can be increased. To produce a lesser amount of thrust, the amplitude of the flapping motion can be decreased. Likewise, the frequency can be increased, in case of a same amplitude.

In an exemplary embodiment of the present flapping wing device, at least two wing arrangements are arranged in a wing arrangement pair (e.g. 12.1 and 12.2 of fig. 2, respectively), comprising a first wing arrangement mounted at one side of the flying apparatus and a second wing arrangement mounted at an opposite side of the flying apparatus, wherein configuration angles (11, α) of both wing arrangements are equal and opposing.

A configuration angle (11, α) is considered to be the angle between a flapping axis (8) and the fuselage (7). In an example of such a device multiple "biplanar" wings are provided.

In an exemplary embodiment the present flapping wing device comprises at least two wing arrangement pairs (WAP)(12) and wherein the device has a two-fold symmetry axis (10) and optionally also a mirror plane (9) (fig. 2). At least two wing arrangements are located at each of the opposite extremities of the fuselage (7), and the two flapping wings of each wing arrangement are arranged with respect to the rotational symmetry (two-fold symmetry axis (10)) of the center of the mass of the aircraft. This arrangement will result in non-aligned thrust vectors in view of yaw. In an example of such a device a rotatably mounted wing arrangement (or wing pair) is controllable and adaptable.

In an exemplary embodiment, at least one configuration angle (11, α) in the present flapping wing device is adjustable during flight, such as by using a servomotor.

In an exemplary embodiment, the present flapping wing device comprises a drive engine (2) drivingly connected to each wing arrangement independently. Here brushed or brushless electric motors can be used which are widely available. In an example of such a device each pair of wings is controlled independently and a position of the wing arrangement is controlled and adaptable.

By independently varying the speed of each drive engine, it is possible to generate a desired lift and have a full attitude control. Each wing arrangement can flap at desired frequency, amplitude and angle. A supplementary drive engine can be included, which controls the frequency and amplitude of two sets of wings, i.e. wing arrangement pair (12).

In an exemplary embodiment, the present flapping wing device comprises at least one of a gyroscope (13) and an accelerometer. A Gyroscope and an accelerometer can be used for stabilization of the device. The present invention can also include a GPS module. A Gyroscope can sense rotation, whereas the accelerometer cannot. At present the capabilities of the gyroscope are preferred as information can be processed quickly and therefore control is almost instantly. In an example of such a device each a position of the wing arrangement is therewith controlled and adaptable.

In an exemplary embodiment, the controller is connected to each drive engine and a sensor, where-in said controller is arranged to control the driving means using attitude data obtained from the sensor. The control system can control the orientation of the flapping wing device, by means of attitude data received from the sensor. In an example of such a device a position thereof is controlled independently and a position of the wing arrangement is controlled and adaptable.

In a second aspect, the invention relates to a device with a wing arrangement comprising a first and a second wing, which are pivotal relative to each other, wherein both wings comprise a wing area, and a leading edge, wherein driving means can provide movement of both wings relative to each other, characterized in that each leading edge is rigid and each wing area is resilient, wherein both wings can be in a first position, wherein both leading edges and both wing areas are substantially parallel and adjoining, and a second position wherein both leading edges and both wing areas are positioned at an angle $(6,\gamma)$ and form a V-shape; and wherein both wings are movable between the first and second position in anti-phase. The V-shape configuration makes sure that four wings are not exactly perpendicular.

In an exemplary embodiment, the present device comprises a wing arrangement wherein the angle between the first and second wing in the second position is controllable. In an example the angle of the second position may be varied from 10-120 degrees.

In an exemplary embodiment, the present device comprises a wing arrangement wherein the angular velocity of the first and second wing is controllable. It is noted that the term "angular velocity" at least partly overlaps in a functional/physical aspect with the term "flapping frequency" used in scientific literature. The control system can control angular velocity of the first and second wing of an arrangement independently. In an example thereof a first wing arrangement may have a first angular velocity, whereas, at a same moment in time, a second wing arrangement may have a second, and different from the first, angular velocity. In an example therewith differential thrust between left and right, or likewise front and back, and combinations thereof, is provided.

The present device may further comprise at least one of a sensor, such as a chemical sensor, such as a sensor for detecting smoke, CO, a chemical species, a remote control, a memory, the memory comprising flight information, such as for performing a navigation loop, for flying in an "autonomous mode", an optical camera, an infrared camera, etc. As such the present device may perform various tasks, such as inspection of a specific location.

The invention is further detailed by the accompanying figures, which are exemplary and explanatory of nature and are not limiting the scope of the invention. To the person skilled in the art it may be clear that many variants, being obvious or not, may be conceivable falling within the scope of protection, defined by the present claims.

The invention although described in detailed explanatory context may be best understood in conjunction with the accompanying exemplary embodiments and figures.

SUMMARY OF THE FIGURES

Fig. 1a-d show a schematic layout of the present pairs of flapping wings.

Fig. 2 shows a schematic top view of the present device

Fig. 3 shows attitude parameters. Figure 3 is copied from DIY, Arduino, Quadrirotor, http://theboredengineers.com/2012/05/the-quadcopter-basics/.

Fig. 4 shows schematics of changing a thrust vector.

DETAILED DESCRIPTION OF THE FIGURES

The figures have been detailed throughout the description.

In the figures:

1 Traditional crank rocker flapping mechanism
2 Electric motor (1 per pair)
3 Wing arrangement
4 Flapping motions
4.A both leading edges and both wing areas are positioned at an angle and form a V-shape
4.B both leading edges and both wing areas are substantially parallel and adjoining
5 Several independent thrust vectors
6 V-shape angle
7 Fuselage
8 Flapping axis
9 Mirror
10 Two fold symmetry axis
11 Configuration angle (α)
12 Wing pair arrangement (WPA)
12.1 WPA1

12.2 WPA2
13 Gyroscope or accelerometer
14 Power source
15 Yaw
16 Roll
17 Pitch
18 Leading edge
19 wing area
20 single pivot point
21 trailing edge

Fig. 1b shows a side view of a configuration with three wing arrangements, of which one is rotatably mounted. In the figure the leading edge 18 and the wing area 19 are shown.

Fig. 1c provides a side view of figure 1a. The central arrows indicate that the thrust vectors provided by the wing arrangements are slightly out of plane (10-20 degrees).

Fig. 1d provides a top view of figure 1a. The arrows indicate that the thrust vectors provided by the wing arrangements are slightly out of plane (10-20 degrees), of which two are pointing upwards and two are pointing downwards. As such e.g. yaw control is provided. In the figure a single pivot point 20 is shown.

Fig. 4 shows schematics of changing a thrust vector. With respect to the leading edge 18 the wing foil representing a wing area 19 is rotated by moving the trailing edge 21; the exemplary rotation is indicated with a dotted arrow. The wing area goes from a first position (solid lines) to a second position (intermitted line). As a result the thrust vector, indicated with a line in the top part of the figure, rotates accordingly.

It should be appreciated that for commercial application it may be preferable to use one or more variations of the present system, which would similar be to the ones disclosed in the present application and are within the spirit of the invention.

In general, with reference to fig. 4 it is noted that a thrust vector 5 substantially perpendicular is to the flapping plane. However, if the wing area is rotated, the thrust vector rotates as well, and as a consequence the thrust vector is no longer "substantially" perpendicular to the flapping plane, which flapping plane remains substantially the same when the wing area is rotated. For the present device such a rotation is considered to be performed intentionally.

CLAIMS

1. A mini flapping wing device for flying, comprising a driver (2), and a connection for a power source (14),

characterized in that it comprises at least three wing arrangements (3,WPA), preferably at least four wing arrangements, each wing arrangement extending outwards at a side of the device, wherein each wing arrangement can provide an independent thrust vector,

the wing arrangement comprising a first and a second wing which are pivotal relative to each other, wherein both wings comprise a wing area (19), and a leading edge (18);

wherein the driver provides movement of both wings relative to each other,

wherein each leading edge is rigid and each wing area is resilient, wherein both wings can be in a first position (4B), wherein both leading edges and both wing areas are close to one and another, such as substantially parallel and adjoining, and a second position (4A) wherein both leading edges and both wing areas are positioned at a larger angle (γ, 6) and form a V-shape;

wherein both wings are movable between the first and second position in anti-phase, and

a controller for independently adapting thrust vectors of the wing arrangements in size and optionally in direction.

2. A mini flapping wing device for flying according to claim 1, **characterized in that** at least one wing arrangement is rotatably mounted on the mini flapping wing device via a single pivot point (20) for both wings or via a pivot point for each wing, for attitude control, specifically yaw control.

3. A mini flapping wing device for flying according to claim 1 or 2, **characterized in that** at least two wing arrangements are arranged in a wing arrangement pair, comprising a first wing arrangement mounted at one side of the flying apparatus and a second wing arrangement mounted at an opposite side of the flying apparatus, wherein configuration angles (10) of both wing arrangements are equal and opposing.

4. A mini flapping wing device for flying according

to any one of claims 1-3, **characterized in that** it comprises at least two wing arrangement pairs and wherein the device has a two-fold symmetry axis (9)and optionally also a mirror plane (8).

5. A mini flapping wing device for flying according any one of claims 1-4, **characterized in that** at least one configuration angle (10) is adjustable during flight.

6. A mini flapping wing device for flying according to any one of claims 1-5, **characterized in that** it comprises a drive engine drivingly connected to each wing arrangement independently.

7. A mini flapping wing device for flying according to any one of claims 1-6, **characterized in that** it comprises at least one of a gyroscope and an accelerometer.

8. A mini flapping wing device for flying according to any one of claims 1-7, **characterized in that** it comprises a controller connected to each drive engine and a sensor, wherein said controller is arranged to control the driving means using attitude data obtained from the sensor.

9. A wing arrangement (3,WPA) for a mini flapping wing device for flying comprising a first and a second wing which are pivotal relative to each other, wherein both wings comprise a wing area (19), and a leading edge (18);

wherein driving means (2) can provide movement of both wings relative to each other, **characterized in that** each leading edge is rigid and each wing area is resilient, wherein both wings can be in a first position (4B), wherein both leading edges and both wing areas are close to one and another, such as substantially parallel and adjoining, and a second position (4A) wherein both leading edges and both wing areas are positioned at a larger angle and form a V-shape; and

wherein both wings are movable between the first and second position in anti-phase.

10. A wing arrangement according to claim 9, **characterized in that** the angle between the first and second wing in the second position is controllable.

11. A wing arrangement according to claim 9 or 10, characterized in that the angular velocity of the first and second wing is controllable.

Figure 1a

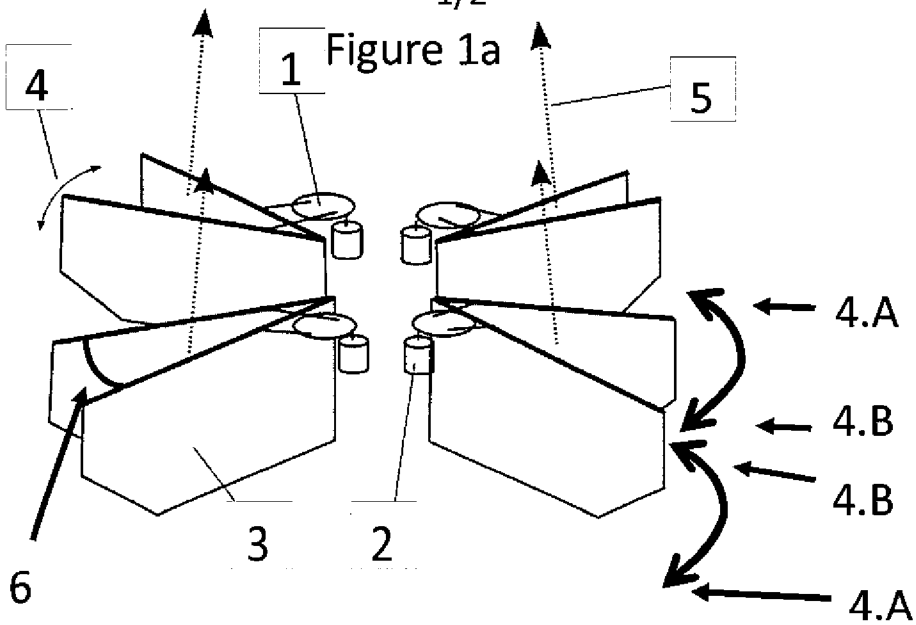


Figure 1b

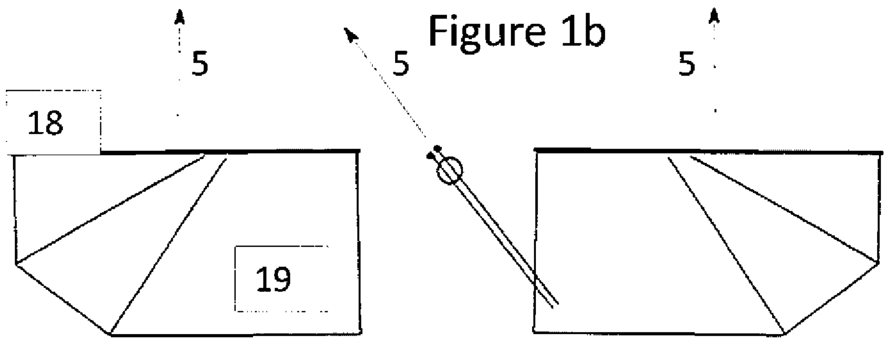
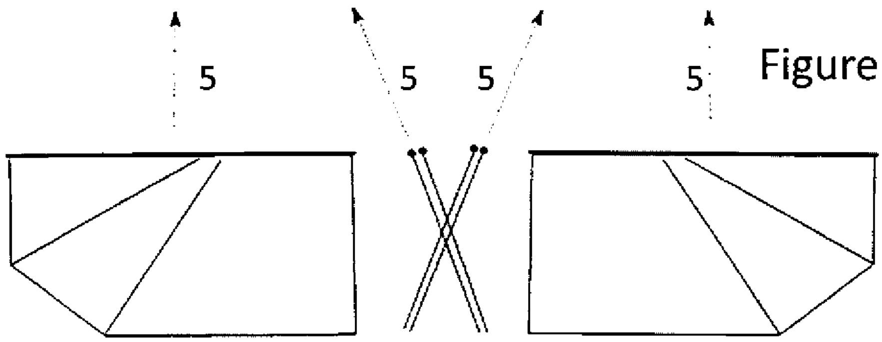


Figure 1c



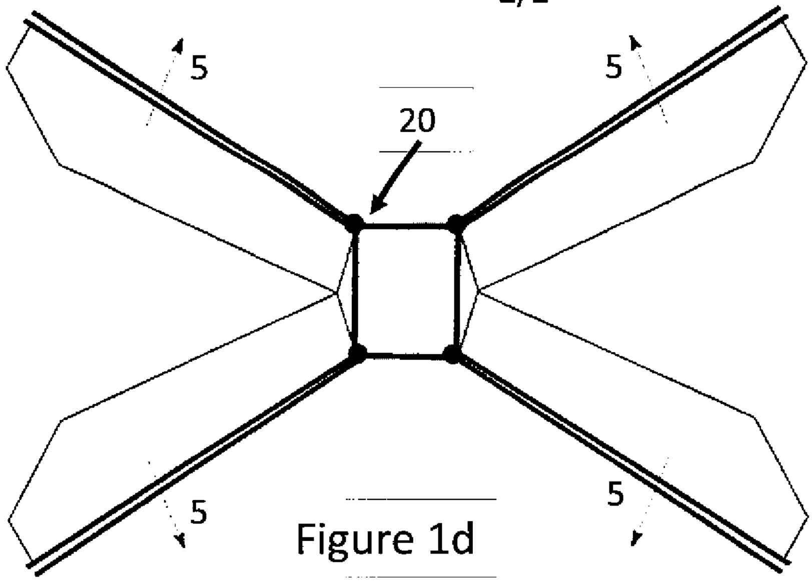
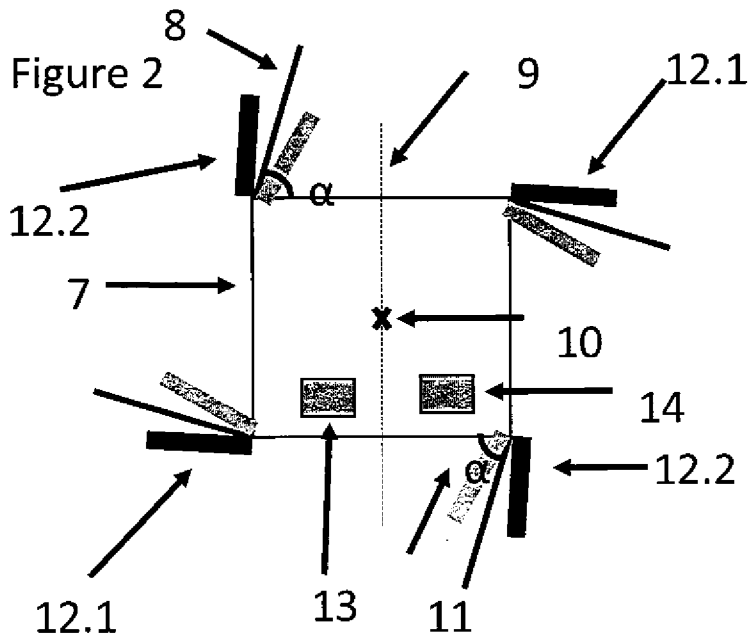


Figure 1d

Figure 2



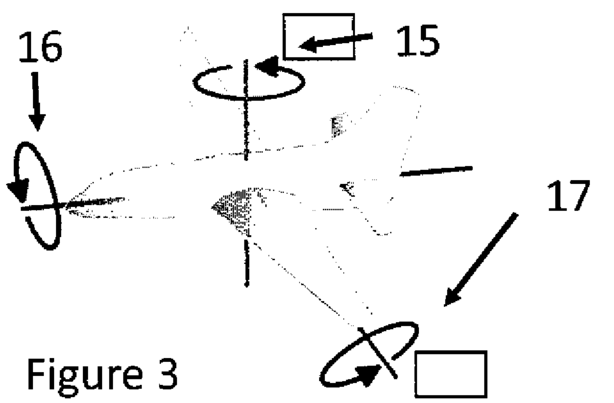
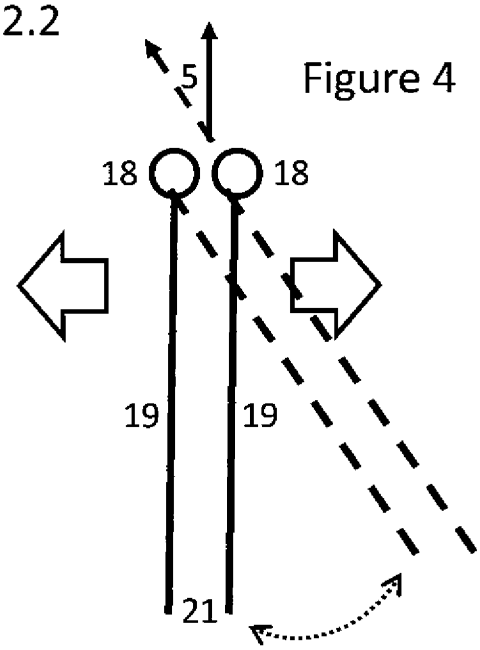


Figure 3

Figure 4



INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2017/050033

A. CLASSIFICATION OF SUBJECT MATTER
INV. B64C33/02 B64C39/00
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)
B64C

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	paragraphs [0028] - [0040]; figures 1, 3, 4, 5	5,7,8,10

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Y	US 2005/269447 A1 (CHRONISTER NATHAN J [US]) 8 December 2005 (2005-12-08)	7
A	paragraphs [0034], [0035]	1,9-11

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search
28 March 2017

Date of mailing of the international search report
07/04/2017

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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2017/050033

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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