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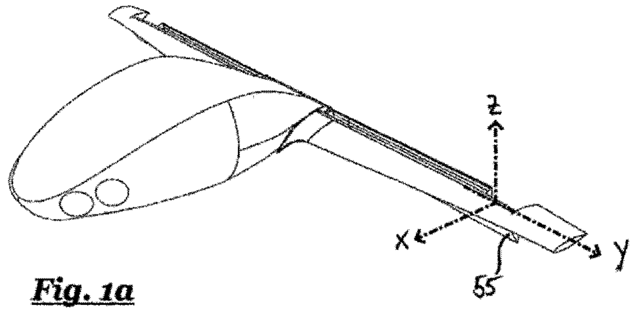

Fig. 1a

(57) **Abstract:** The invention refers to an aircraft (1, 3), particularly an aircraft (1, 3) capable of vertical take-off and landing, comprising a fuselage (3, 4), and a variable lift body (5, 7) defining an aerofoil (51, 53) and being moveably attached to the fuselage (3, 4), wherein the variable lift body (5, 7) is pivotable around a first axis extending in the wing (4) span direction. wherein a rotary actor (11) adapted to cause the variable lift body (5, 7) to pivot in relation to the fuselage (3, 4) arranged within the aerofoil.

WO 2022/175065 A1

Aircraft

Field

The invention relates to an aircraft, in particular an aircraft capable of vertical take-off and landing (VTOL).

Related Art

Aircraft capable of vertical take-off and landing (VTOL) have the potential to incorporate both the advantages of helicopters, namely starting and landing using the limited space and/or in rough terrain, as well as the advantages of conventional aircraft, such as high traveling velocities and cruising efficiently, with one another. Challenges in the design of VTOL aircraft include the necessity that, on the one hand, large propeller areas are required for the provision of a sufficient mass flow to create thrust into the vertical direction for takeoff or landing, and at the same time limit the energy consumption. On the other hand, propellers must be configured for the least amount of aerodynamic resistance for cruising, when the lift is dynamically created by means of suitable wing profiles. The reduction of energy consumption is particularly relevant in the case of electrically powered VTOL aircraft (eVTOL) such as the eVTOL aircraft described in Lilium®'s patent applications US 2016/0023754 A1 or US 2016/03115221 A1.

Vertical take-off aircraft designed for hovering flight comprise engines that can be rotated about a pivot axis. During take-off, landing, or hovering flight, the engines are placed in a take-off/landing position in which the direction of thrust is oriented vertically. In order to accelerate the aircraft after take-off, the engines may be continuously pivoted in such a way that the direction of thrust is ultimately aligned with a cruise flight direction. The thrust provided by the engine to power the aircraft is transferred towards the fuselage through a mechanical system attaching the engine to the fuselage and allowing the engine to be pivoted in relation to the fuselage. The mechanical system has to be capable of reliably holding the engine in a desired, well-defined position with regard to the fuselage. In order to allow for energy-efficient cruising, hovering, take-off and/or landing, the mechanical system should be as lightweight as possible. Especially for energy-efficient cruising, the mechanical system should add as little drag as possible. Particularly for aircraft having primary lift bodies designed as larger and statically load-bearing elements fastened to the fuselage (wings) and the engine being attached to the fuselage via a primary lift body, it is important that mechanical stresses for example due to bending of the primary lift bodies around the longitudinal and/or vertical axis of the aircraft, do not impair the workings of the engine.

For conventional aircraft, US 4,773,620 A describes a device for actuating aircraft control surfaces having an actuator disposed within the control surface. The control surface described is an aileron pivotably attached to a wing structural box. The actuator is a longitudinally extendable hydraulic piston which is, on one hand, fastened to the wing structural box eccentrically with regard to the pivot axis of the control surface, and, on the other hand, rearwardly within the control surface. By changing the length of the hydraulic piston actuator, the pivoting position of the control surface in relation to the wing structural box can be controlled. The hydraulic piston actuator is a heavy and bulky. It is a further disadvantage of the described design that, in order to achieve large pivoting angles, such as required for control surfaces for example of VTOL aircraft, the mechanical system including the piston actuator would need to breach the aerofoil, thereby significantly increasing drag. A loss of pressure of the hydraulic actuator would cause the control surface to pivot uncontrollably.

Description

It is an object of the invention to overcome the disadvantages of the prior art, in particular to provide mechanically reliable and energy saving means for attaching an engine or other variable lift body to the fuselage of an aircraft, particularly a VTOL, more particularly an eVTOL. This objective is solved by the subject matter of independent claims 1 and 4.

A first aspect of the invention relates to an aircraft, in particular an aircraft capable of vertical takeoff and landing, comprising a fuselage and a variable lift body. The variable lift body defines an aerofoil and is movably attached to the fuselage. The variable lift body is pivotable with regard to the fuselage around a first axis extending in the wing span direction. The variable lift body may for example be a control canard. The first axis may correspond to a lateral axis of the aircraft and/or a pitch axis of the aircraft. The aircraft may be provided with the primary lift body fastened to the fuselage, such that the variable lift body is pivotable also with regard to the primary lift body around the first axis. In particular, the first axis extends in the wing span direction of the variable lift body. The first axis may be defined by a wing span direction of the primary lift body. The primary lift body may be designed larger than the variable lift body and as a statically load-bearing element. The variable lift body may for instance be realized in the form of the landing flap or an aileron.

According to the first aspect of the invention, the aircraft further comprises a rotary actor adapted to cause the variable lift body to pivot in relation to the fuselage. The rotary actor is arranged within the aerofoil defined by the variable lift body. It may be preferred that the rotary actor includes a rotary electromotor, such as a rotary servo motor or stepper motor. The rotary actor may include a transmission for transforming relatively little torque provided at relatively large rpm by the electromotor into relatively large torque provided at relatively little rpm at an output of the rotary actor. In particular, the rotary actor comprises a self-locking transmission. The rotary actor preferably includes a harmonic gearing. The rotary actuator, in particular the transmission, may be configured to limit the angular range of the pivoting movement of the variable lift body with regard to the fuselage around the first axis to a predefined angular pivoting range, in particular between a cruising position and of vertical takeoff/landing position. The angular pivoting range limited by the rotary actor may be defined to be less than 180°, in particular less than 135°. Alternatively or additionally, the angular pivoting range allowed for by the rotary actor may be at least 60°, in particular at least 90°, more particularly at least 100°. The angular pivoting range may be in the range of 125° ±5°. It may be preferred that the variable lift body may have a primary arrangement, in particular corresponding to a horizontal direction for an aircraft sitting on a horizontally level ground with its undercarriage. In relation to the primary arrangement, the angular pivoting range may be limited to no more than 135 ° downwards, in particular no more than 115 ° downwards, more particularly no more than 90° downwards. Alternatively or additionally, in relation to the primary arrangement, the angular pivoting range may be limited to no more than 30° upwards, in particular no more than 10° upwards, more particularly no more than 5° upwards. Alternatively or additionally, in relation to the primary arrangement, the angular pivoting range may be at least 60° downwards, in particular at least 90°, preferably at least 100° downwards. Alternatively or additionally, in relation to the primary arrangement, the angular pivoting range may be at least 0° upwards, in particular at least 5° upwards, preferably at least 10° upwards. Alternatively, for an embodiment such as a front canard structure realizing a variable lift body, the angular pivoting range shall be in the range of at least 270°, preferably 360 ° or more. It is preferred that the aerofoil surrounds the rotary actor completely, particularly in the longitudinal and/or vertical direction of the aircraft, in particular such that the drag of the variable lift body remains unaffected by the geometry of the rotary actor. The aerofoil of the variable lift body may realize a housing encasing the rotary actor, in particular regardless of the pivoting position of the variable lift body with regard to the fuselage.

According to one embodiment of an aircraft, the variable lift body is fastened to the fuselage with at least one joint assembly adapted for transferring torque around the first axis from the variable lift body to the fuselage. The rotary actor is arranged adjacent to the joint assembly in the direction of the first axis. In the direction of the first axis, it may be preferred that the rotary actor is arranged in closer proximity to the fuselage than the joint assembly, or vice versa. A transmission of the rotary actor is preferably arranged between an electromotor and the joint assembly in the direction of the first axis. In particular, the rotary actor may be arranged at the forward and of the variable lift body. By arranging the rotary actor in close proximity with the joint assembly, a favorable weight distribution and small space consumption can be achieved, which allows to improve aerodynamics and thereby efficiency.

In another embodiment, which may be combined with the aforementioned one, the rotary actor has an axis of rotation parallel to the first axis. In particular, the axis of rotation of the rotary actor may be coaxial with the pivoting axis. The first axis may correspond to the pitch axis of the aircraft.

According to a second aspect of the invention, which may be combined with the first aspect of the invention, an aircraft comprises a fuselage and a variable lift body movably attached to the fuselage. The variable lift body is pivotable around the first axis extending in the wing span direction. Preferably, the wing span direction of the variable lift body defines the first axis. The first axis may correspond to the pitch axis of the aircraft and/or to the lateral axis of the aircraft. The variable lift body may for example be a control canard. The aircraft may be provided with the primary lift body fastened to the fuselage, such that the variable lift body is pivotable also with regard to the primary lift body around the first axis. The first axis may be defined by a wing span direction of the primary lift body. The primary lift body may be designed larger than the variable lift body and as a statically load-bearing element. The variable lift body may for instance be realized in the form of the landing flap or an aileron. The variable lift body is fastened to the fuselage with at least one joint assembly adapted for transferring torque around the first axis from the variable lift body to the fuselage. The joint assembly may be configured to limit the angular range of the pivoting movement of the variable lift body with regard to the fuselage around the first axis to a predefined angular pivoting range, in particular between a cruising position and of vertical takeoff/landing position. The angular pivoting range limited by the joint assembly may be defined to be less than 180°, in particular less than 135°, more particularly less than 110°. Alternatively or additionally, the angular pivoting range allowed for by the joint assembly may be at least 45°, in particular at least 60°, more particularly at least 80°.

According to the second aspect of the invention, the joint assembly is adapted to allow freedom of rotational movement around a second axis crosswise, in particular perpendicular, to the first axis. The second axis is different from the first axis. The second axis may for instance correspond to the longitudinal axis and/or roll axis of the aircraft. Alternatively, the second axis may correspond to the vertical axis and/or yaw axis of the aircraft. It may be preferred, that the joint assembly is adapted to transfer substantially less torque around the second axis between the variable lift body and the fuselage or any intermediate component than around the first axis. In particular, the joint assembly is adapted to transfer less than 10%, preferably no more than 5% torque around the second axis in relation to the torque transferred around the first axis. The joint assembly is particularly adapted not to transfer any torque around the second axis between the variable lift body and the fuselage or any intermediate component, such as in some cases a primary lift body. For example in cases where the second axis corresponds to the roll axis of the aircraft, an aircraft according to the second aspect of the invention is rendered capable by the joint assembly to liberate the variable lift body which may include an engine from torque or the like due to static load of the aircraft primary lift body, for instance static load due to the weight of the primary lift body held by an undercarriage attached to the fuselage; or static load due to the weight of the lift body during flight when the primary lift body provides the lifting force to the aircraft.

In a further development of the second aspect of the invention, the joint assembly is adapted to allow freedom of rotational movement around a third axis crosswise, in particular perpendicular, to the first axis and the second axis. The third axis is different from both the first and second axis. The third axis may correspond to the vertical axis and/or yaw axis of the aircraft. Alternatively, the third axis may for instance correspond to the longitudinal axis and/or roll axis of the aircraft. It may be preferred, that the joint assembly is adapted to transfer substantially less torque around the third axis between the variable lift body and the fuselage or any intermediate component than around the first axis. In particular, the joint assembly is adapted to transfer less than 10%, preferably no more than 5%, torque around the third axis in relation to the torque transferred around the first axis. The joint assembly is particularly adapted not to transfer any torque around the third axis between the variable lift body and the fuselage or any intermediate component, such as in some cases a primary lift body. For example, in cases where the third axis corresponds to the yaw axis of the aircraft, an aircraft according to the further development of the second aspect of the invention is rendered capable by the joint assembly to liberate the variable lift body which may include an engine from torque or the like due to load of the aircraft primary lift body due to drag-forces while cruising at a high forward velocity.

According to a further development of the second aspect of the invention that may be combined with the aforementioned one, the joint assembly includes at least one spherical joint, in particular exactly one spherical joint, attaching the variable lift body to the fuselage. A spherical joint includes a concave reception and a spherical member arranged within the concave reception and rotatable relative to the spherical member around at least two, preferably around three different axes of rotation. The spherical member may be provided with one or two, preferably diametrically opposite, radial extensions, such as a pin, to attach the spherical member to another mechanical component, such as the fuselage, the variable lift body or the linkage. In the embodiment, for each respective one of the first, second and third spherical joint, one of the concave reception and the spherical body is firmly coupled with either one of the variable lift body, the linkage, or the fuselage. Preferably, the first spherical joint is attached to the variable lift body and the primary lift body below the second and third spherical joint. It may be preferred that the first and second spherical joint are rigidly attached to an output shaft of the rotary actor and that a support section of the rotary actor is rigidly attached to the variable lift body, or vice versa, wherein the output shaft of the support section of the rotary actor are rotatable relative to one another, preferably around the first axis.

In a further development of the second aspect of the invention, the joint assembly includes at least one linkage attaching the variable lift body to the fuselage. A second spherical joint connects the variable lift body to the linkage, and a third spherical joint connects the fuselage to the linkage. The joint assembly may include exactly two linkages, each having a respective second and third spherical joint. The linkage may be realized as a monobloc and/or rigid rod or beam. In particular , the joint assembly includes a first spherical joint attaching variable lift body to the fuselage, a second spherical joint attaching the variable lift body to a linkage, and a third spherical joint attaching the fuselage to the linkage.

According to one further development of the second aspect, that may be combined with the previous ones, the joint assembly includes several spherical joints, such as two second spherical joints and two third spherical joints, or one first, one second and one third spherical joint, arranged in a single plane. The single plane in which the several spherical joints are arranged may extend crosswise, in particular perpendicular, to the first axis, particularly in a resting state of the joint assembly. In a particular joint assembly, the distance between the first and second spherical member, the distance between the first and third spherical and the distance between the second and third spherical member may be constant. Preferably, the distance between the second and third spherical joint corresponding to the length of the linkage is no larger than, preferably smaller than, the distance between the first spherical joint and either one of the second or third spherical joint, which may be the same. The first, second and/or third spherical joint may be configured to receive and transmit forces in at least one of the first, second and third, direction. The first spherical member may be rotatably held in a reception of either the fuselage or the variable lift body, whereas a pin extending radially from the first spherical member is rigidly attached to the other one of the variable lift body or fuselage. The second spherical member may be rotatably held in a reception of either the variable lift body or linkage, whereas a pin extending radially from the second spherical member is rigidly attached to the other one of linkage or variable lift body. The third spherical member may be rotatably held in a reception of either the fuselage or linkage, whereas a pin extending radially from the third spherical member is rigidly attached to the other one of linkage or fuselage. It shall be clear that when referring to a connection to the fuselage herein, the connection can refer to indirect connection to the fuselage, for instance directly to a primary lift body which is rigidly attached to the fuselage. This embodiment has been shown to allow for the transmission of large torque around the first axis while relieving the variable lift body from receiving torque from the fuselage around the second or third axis. Furthermore, this embodiment has shown to require only little space and allow for a lightweight solution.

Alternatively, in one embodiment of an aircraft, the joint assembly includes a double cardan joint connecting the variable lift body to the fuselage. In another alternative embodiment of an aircraft, the joint assembly includes a crown spine connecting the variable lift body to the fuselage. In yet another alternative embodiment, the joint assembly includes a jaw coupling connecting the variable lift body to the fuselage. The double Cardan connection, crown spine connection, or jaw coupling may comprise a torque input shaft rigidly connected to the variable lift member, particularly an output shaft of the rotary actor, wherein the input shaft extends in the direction of the first axis, particularly in a resting state of the joint assembly. Alternatively or additionally, the double Cardan connection, the crown spine connection, or jaw coupling may comprise a torque output shaft rigidly connected to the fuselage, wherein the output shaft extends in the direction of the first axis, particularly in a resting state of the joint assembly.

According to a further alternative of the invention, the joint assembly includes at least one solid body spring connecting the variable lift body to the fuselage. The solid body spring may be designed in a manner known to the skilled person such that torque is only transferred around one first axis whereas the second or third axis crosswise, in particular perpendicular, to the first axis substantially do not transfer torque.

According to one embodiment, the variable lift body is fastened to the fuselage directly or indirectly, for instance via the primary lift body, using exactly two, exactly three or more joint assemblies distanced apart from one another in the direction of the first axis. The first and second joint assembly attaching the variable lift body to the fuselage may be identical or different from another. By attaching the variable lift body exclusively with joint assemblies transferring torque around the first axis while not necessarily around any other axis, the variable lift body can be held to the fuselage in such a manner that only torque necessary for lifting, steering and/or propulsion of the aircraft is transferred.

Alternatively, the variable lift body is fastened to the fuselage, directly or indirectly, for instance via the primary lift body, using exactly one joint assembly and at least one bearing distanced apart from the joint assembly in the direction of the first axis. The bearing may be configured to receive and transmit forces between the fuselage and the variable lift body in at least one of the first, second and third, direction, in particular in at least two of the first, second and third direction, preferably in all of the first, second and third direction. In particular, the bearing allows rotational freedom of movement around the first, second and/or third axis. The bearing may be configured to transfer a torque from the variable lift body to the fuselage around a first, second and/or third axis. By using on the one hand a bearing and on the other hand a joint assembly to attach the variable lift body to the fuselage, a particularly weight-efficient connection may be realized which sufficiently liberates the variable lift body or from receiving any detrimental torque around any other than the first axis.

In one embodiment of an aircraft, the variable lift body includes an engine adapted to provide thrust for the aircraft for at least one of takeoff, landing, or cruising. The variable lift body may include an engine for providing thrust to the aircraft. The variable lift body in particular includes an engine pivotable in relation to the fuselage between a cruising flight position in which the thrust direction of the engine is aligned with the longitudinal axis of the aircraft, and a takeoff and landing position or hover position in which the thrust direction of the engine is angled towards the vertical axis of the aircraft. In particular, in the cruising flight position, the thrust direction of the engine may be parallel to the heading direction or the roll axis or may be inclined to the heading direction or the roll axis by an angle smaller than 15°. In particular, in the hover position, the thrust direction of the engine may be parallel to the vertical direction or may be inclined to the vertical axis or yaw axis by an angle smaller than 15°. The variable lift body including an engine pivotably attached to the fuselage of an aircraft may be described as a thrust vectoring system. The aircraft can include at least one variable lift body including an engine in the rear of the aircraft, in particular in combination with a primary lift body. Alternatively or additionally, the aircraft can include at least one variable lift body including an engine in the front of the aircraft, in particular in the manner of, instead of, or in combination with a canard. Alternatively or additionally, the aircraft can include at least one variable lift body including an engine attached to the central section of the aircraft with regard to its lengthwise extension, in particular in combination with a primary lift body. The aircraft can include a plurality of engines arranged side-by-side in a row transversely to the direction of flow and/or in the direction of the first axis. It may be preferred that the at least one engine is an electrically driven ducted fan.

In another embodiment of an aircraft, that may be combined with the aforementioned one, the variable lift body includes an aerodynamic control structure, such as a control canard, a canard structure, an aileron or landing flap.

In yet another embodiment of an aircraft, that may be combined with one or more of the aforementioned ones, the aircraft includes at least one primary lift body, such as a canard structure and/or a wing, which is stationarily attached to the fuselage, wherein the variable lift body is attached to the primary lift body. The primary lift body may have a relatively large surface area extending in the wing span direction and the longitudinal direction of the aircraft. The primary lift body may be a statically loadbearing element for providing a lifting force during cruising flight of the aircraft in the primary cruise flight direction. It may be preferred that the primary lift body is integrally connected to the fuselage of the aircraft. In particular, the variable lift body is arranged behind the primary lift body with regard to the cruise flight direction of the aircraft.

In another embodiment, the aircraft further comprises another attachment rotatably connecting the variable lift body to the fuselage around the first axis and allowing freedom of linear movement of the variable lift body in the direction of the first axis. The another attachment may include a sliding bearing and a fourth spherical joint. The fourth spherical joint comprises a spherical member rotatably held within a concave reception. The fourth spherical member may be rotatably held in a reception of either the fuselage or the variable lift body, whereas a slidable connection extending radially from the fourth spherical member is rigidly attached to the other one of the variable lift body or fuselage. It may be preferred that the fourth spherical joint is attached to the variable lift body rotatable relative to the first axis. The fourth spherical joint may be configured to receive and transmit forces in at least one of the first, second and third, direction. The another attachment and the joint assembly are rigidly coupled the variable lift member, wherein the another attachment member and the joint assembly are preferably distanced from one another in the direction of the first axis, in particular by at least one third, preferably by at least half, more preferably by at least two thirds, of the extension of the variable lift body in the direction of the first axis. Alternatively, the distance may be less than half, in particular less than one third, of the extension of the variable lift body.

The aircraft may in particular be configured for carrying at least one human passenger, preferably several human passengers, and/or comprising at least one electrically powered flight propulsion system, preferably a flight propulsion system for electronic vertical takeoff and landing.

Brief description of the drawings/figures

Preferred configurations of the invention are described in the dependent claims. The accompanying drawings illustrate the embodiments of the present disclosure and, together with the description, further serve to explain the principles of the embodiments and to enable a person skilled in the pertinent art to make and use the embodiments.

Fig. 1a a perspective view of an aircraft according to the invention comprising a variable lift body arranged in a vertical take-off/landing position;

Fig. 1b a schematic view of the variable lift body according to Fig. 1a;

Fig. 2a a perspective view of the aircraft according to the Fig. 1 wherein the variable lift body is arranged in a tilted position;

Fig. 2b a schematic view of the variable lift body according to Fig. 2a;

Fig. 3 a schematic view of the variable lift body in a cruising position;

Fig. 4a a schematic view of the variable lift body;

Fig. 4b a schematic illustration of a joint assembly used in the variable lift body according to Fig 4a;

Fig. 4c an exemplary embodiment of another attachment coupling of the variable lift member:

Fig. 5 shows a detailed sectional view of the attachment shown in Figure 4c;

Fig. 6 a schematic illustration of another embodiment of a joint assembly; and

Fig. 7 a schematic illustration of a further embodiment of a joint assembly.

The exemplary embodiments of the present disclosure will be described with reference to the accompanying drawings. Elements, features and components that are identical, functionally identical and have the same effect are – insofar as is not stated otherwise – respectively provided with the same reference character.

Reference numeral 1 generally designates an aircraft according to the invention, having as its main constituents a fuselage 3 and a variable lift body 5. The fuselage 3 may be provided with at least one primary lift body 4 rigidly or even integrally attached to the fuselage 3.

Fig. 1a and Fig. 2a show the aircraft 1 having the variable lift body 5 arranged in different pivoting positions in relation to the fuselage 3. Fig. 1a shows the variable lift body 5 including an aileron 55 and a multitude of electrically powered ducted fan engines 53 arranged in a vertical take-off/landing or hovering position which is shown in further detail in Fig. 1b. Fig. 2a shows the same variable lift body 5 in a tilted intermediate pivoting position which may correspond to a state after take-off and before cruise flight or after cruise flight and before landing, which is shown in further detail in Fig. 2b. The multitude of electrically powered ducted fan engines 53 is arranged immediately adjacent one another in the direction of the first axis Y of the aircraft. Fig. 3 shows once again the same variable lift body 5, however, arranged in alignment with the primary lift body 4 and thus in a cruising position in which the direction of thrust T of the engine 53 is aligned with the forward cruise flight direction F. The forward cruise flight direction F may correspond to the longitudinal axis or roll axis X of the aircraft.

In the illustrated embodiment, the variable lift body 5 is rotatably attached to the fuselage 3 via the main or primary lift body 4. In relation to the fuselage 3 of the primary lift body 4, the variable lift body 5 is pivotable around a first axis Y corresponding to the direction of the wing span. The first axis Y may correspond to the lateral axis or pitch axis of the aircraft 1.

The weight of the variable lift body 5 and/or the thrust provided by the engines 53 transferred from the variable lift body 5 to the fuselage 3 through a joint assembly 7 one embodiment of which will be described in further detail below with regard to Figs. 4a and 4b. The joint assembly is configured to transfer torque from the variable lift body 5 to the fuselage 3 and vice versa exclusively around the first axis Y.

The joint assembly 7 is adapted not to transfer torque around a second axis that may correspond to the aircraft's 1 roll axis X nor around a third axis that may correspond to the aircraft's 1 yaw axis Z. Thereby, the joint assembly 7 liberates the engine 53 or other components of the variable lift body 5 from torque loads onto the wing 4 for instance due to drag or lifting forces which may cause a deformation of the wing 4 which should not impair the engine 53 and particularly not impair multiple engines 53 being arranged immediately adjacent one another in a row in the direction of the first axis Y.

Figure 4a shows a perspective schematic sectional view through an exemplary variable lift body 5 that consists mainly of an engine 53 surrounded by an aerofoil 51 defining the aerodynamic streamlining properties of the variable of body 5. Inside of the encasing defined by the aerofoil 51, a rotary actor 11 is arranged which is adapted to set the pivoting position of the variable lift body 5 in relation to the aircraft's 1 fuselage 3. The attachment to the fuselage 3 is realized by means of the joint assembly 7. Another attachment 8 which may include a further joint assembly or another bearing may additionally be provided.

The rotary actor 11 is rigidly connected to the variable lift body 5 through a support section 13. The rotary actor 11 has an output shaft 12 rotatable in relation to the support section 13. The output shaft 12 is rigidly attached to the joint assembly 7 to define the pivoting position of the variable lift body 5 in relation to the fuselage 3. The rotary actor 11 may include an electromotor coupled to a self-locking transmission 14 adapted to provide low angular velocity and high torque to the output shaft 12 from the electromotor. The output shaft 12 and the rotary actor 11 extend coaxially to the first axis Y. In the direction of the first axis Y, the rotary actor 11 is arranged adjacent to the joint assembly 7.

Figure 4b shows an exemplary embodiment of a joint assembly 7 for transferring torque around the first axis Y from the variable lift body lift body 5 to the fuselage 3. In the forward direction of the longitudinal axis X, the joint assembly 7 is attached to a support structure 41 of the primary lift body 4 fastened to the fuselage 3. In the rearward direction with regard to the longitudinal axis X, the joint assembly 7 is attached to the variable lift body 5 through a support ring 83. The support ring 83 houses a crossed roller bearing 80. A torque shaft 84, which is rigidly connected to the output shaft 12 of the rotary actuator 11, is borne by the roller bearing 80.

The torque shaft 84 has two eccentric noses 81, 82 arranged along its outer circumference and protruding radially outwardly from the first axis Y. The first nose 81 is, in the illustrated resting position of the joint assembly 7, arranged vertically below the second nose 82 in a first distance d1. The first nose 81, in the resting position such as shown in figures 4a and 4b, extends approximately horizontally in the direction of the longitudinal axis X of the aircraft from the center of rotation of the torque shaft 84. The first nose 81 includes a concave reception 70 receiving a spheroid from which a pin extends in the direction of the first axis to be connected to the support structure 41. The first nose 81 is connected to the support structure 41 through a first spherical joint 71.

The second nose 82 also includes a concave reception receiving another spheroid from which another pin extends in the direction of the first axis Y to be connected to a linkage 74. Thus, a second spherical joint 72 connects the linkage 74 to the second nose 82. The linkage 74 is formed by two rigid bars extending in parallel, roughly in the direction of the longitudinal axis X of the aircraft 1. Spaced apart by a second distance d2, the linkage 74 connects on the one hand to the second spherical bearing 72 and on the other hand to the third spherical bearing 73. The third spherical bearing 73 connects the linkage 74 to the support structure 41. The support structure 41 forms a concave reception 70 holding a spheroid from which two pin-like 75 extensions protrude in the direction of the first axis Y. The pin -like extensions 75 of the third spherical bearing 73 are connected to the linkage 74. The third spherical bearing 73 is distanced by a third distance d3 from the first spherical bearing 71. The first distance d1 and third distance d3 are approximately the same. The second distance d2 is shorter than the first and third distance d1, d3.

The first, second, and third spherical bearing 71, 72, and 73 allow for rotation of the respective internal spheroid around three mutually perpendicular axes of rotation. However, as the linkage 7 includes three spherical bearings 71, 72, 73 arranged in a triangular arrangement defining a single plane, any relative movement of the linkage 7 along a vector in said plane is a constricted and thus torque is transferred. In the resting position shown in figure 4b, the plane defined by the triangular arrangement of the spherical bearings 71, 72 and 73 is oriented perpendicular to the first axis Y, in other words, the first axis Y is a normal vector of said plane.

Any relative movement of the fuselage 3 in relation to the variable lift member 5 along a vector deviating from said plane is uninhibited by the linkage 7 at least for a certain range. Thus, torque transfer from the variable lift body 5 through the linkage 7 to the fuselage 3, and vice versa, around the second or third axes X, Z, is avoided.

Fig. 4c shows an exemplary embodiment of the another attachment 8 comprising a single spherical bearing 78. Fig. 5 shows a detailed sectional view of the attachment 8 shown in Figure 4c. The exemplary attachment 8 described herein could be used in conjunction with any joint assembly 7 described herein.

The spherical bearing 78 moveably connects the variable lift body 5 to the fuselage 3. The spherical bearing 78 of the attachment 8 allows for a rotation of the variable lift body 5 about the first axis Y in relation to the primary lift body 4. Furthermore, the spherical bearing 78 is slidable in the direction of the first axis Y along the pin 85. Thereby, the spherical bearing 78 allows for a linear displacement of the variable lift body 5 with regard to the primary lift body 4 in the area of the attachment 8. This allows for displacement in case of a deformation of either the primary lift body 4 or the secondary lift body 5 in relation to the lateral axis Y defined by the lateral extension of the variable lift body 5.

The pin 85 attaches the bearing 78 to the flap bracket 86. The flap bracket is rigidly coupled to or formed as a single piece with the variable lift body 5. The pin 85 extends through a reception 70 in the wing bracket 48, in which the spherical bearing 78 is arranged.

Fig. 6 shows an alternative embodiment of a joint assembly 7. The joint assembly is of particularly simple design having only one spherical bearing 71. The single spherical bearing 71 of the joint assembly exemplarily shown in Fig. 6 directly connects the rotary actor 11 of the variable lift body 5 to the support structure 41 of the primary lift body 4. The support structure 41 in this case may be realized, for example, as a wing spar or an aft spar. The rotary actor may be rigidly attached to the variable lift structure 5 through several support lugs 85. The spherical bearing 71 is held to the rotary actor 11 with a lever-like nose 82 extending radially, essentially in the direction of a second, preferably longitudinal, axis X from the rotary actor 11, the rotary axis of which corresponds to the first axis Y. The spherical bearing 71 allows to introduce torque from the rotary actor 11 around the first axis Y into the primary lift body 4 while permitting free rotary movement with regard to the second and third (longitudinal and vertical) axes of the variable lift body 5 regard to the primary lift body 4. A joint assembly 7 as shown in Fig. 6 may be combined with two or more additional bearings 8 (not shown) for attachment of the variable lift body.

Yet another alternative embodiment of a joint assembly 7 is shown in Fig. 7 which allows to transfer torque around the first axis Y from the rotary actor 11 contained within the airfoil 51 of the variable lift body 5 to the fuselage through a primary lift body 4. The joint assembly comprises two linkages 74 and four spherical bearings 72, 73. Each linkage 74 has one respective second spherical bearing 72 for attachment to the support structure 41 of the primary lift body 4, and one respective third spherical bearing 73 for attachment to the variable lift body 5. A joint assembly 7 as shown in Fig. 7 may be combined with two or more additional bearings 8 (not shown) for attachment of the variable lift body.

The spherical bearings 74 of the joint assembly 7 can have the same second length d2, or different second lengths (not shown). The first distance d1 of the spherical joints 73 rigidly attached to the variable lift body 5 is larger than the fourth distance d4 of the spherical joints 72 rigidly attached to the primary lift body 4.

The features disclosed in the above description, in the figures and in the claims can be of importance both individually and in any combination for the realization of the invention in its various configurations.

Reference Numbers

1	aircraft
3	fuselage
4	primary lift body
5	variable lift body
7	joint assembly
8	attachment
11	rotary actuator
12	output shaft
13	support section
14	transmission
41	support structure
48	wing bracket
51	aerofoil
53	engine
55	aileron
70	reception
71, 72, 73, 78	spherical joint
74	linkage
75, 85	pin
80	roller bearing
81, 82	nose
83	support ring
84	torque shaft
85	support lug
86	flap bracket

d1	first distance
d2	second distance
d3	third distance
d4	fourth distance
F	cruise flight direction
T	thrust direction
X	roll axis; longitudinal axis
Y	first axis; pitch axis; lateral axis
Z	yaw axis; vertical axis

Claims

1. Aircraft (1), particularly an aircraft capable of vertical take-off and landing, comprising:
a fuselage (3), and a variable lift body (5) defining an aerofoil (51) and being moveably attached to the fuselage (3), wherein the variable lift body (5) is pivotable around a first axis (Y) extending in the wing span direction;
c h a r a c t e r i z e d by a rotary actor (11) adapted to cause the variable lift body (5) to pivot in relation to the fuselage (3) arranged within the aerofoil (51).

2. Aircraft according to claim 1, wherein the variable lift body (5) is fastened to the fuselage (3) with at least one joint assembly (7) adapted for transferring torque around the first axis (Y) from the variable lift body (5) to the fuselage (3),
c h a r a c t e r i z e d in that the rotary actor (11) is arranged adjacent to the joint assembly (7) in the direction of the first axis (Y).

3. Aircraft according to claim 1 or 2, c h a r a c t e r i z e d in that the rotary actor (11) has axis of rotation parallel to first axis (Y).

4. Aircraft (1), particularly an aircraft capable of vertical take-off and landing, in particular according to one of the preceding claims, comprising:
a fuselage (3), and a variable lift body (5) being moveably attached to the fuselage (3), wherein the variable lift body (5) is pivotable around a first axis (Y) extending in the wing span direction;
wherein the variable lift body (5) is fastened to the fuselage (3) with at least one joint assembly (7) adapted for transferring torque around the first axis (Y) from the variable lift body (5) to the fuselage (3),
c h a r a c t e r i z e d in that the joint assembly (7) is adapted to allow freedom of rotational movement around a second axis (X, Z) crosswise, in particular perpendicular, to the first axis (Y).

5. Aircraft according to claim 4, c h a r a c t e r i z e d in that the joint assembly (7) allows freedom of rotational movement around a third axis (Z, X) crosswise, in particular perpendicular, to the first axis (Y) and to the second axis (X, Z).

6. Aircraft according to claim 4 or 5, c h a r a c t e r i z e d in that the joint assembly (7) includes at least one spherical joint (71, 72, 73), in particular exactly one spherical joint (71), attaching variable lift body (5) to the fuselage (3).

7. Aircraft according to claim 6, c h a r a c t e r i z e d in that the joint assembly (7) includes at least one linkage (74) attaching variable lift body (5) to the fuselage (3), wherein a second spherical joint (72) connects variable lift body (5) to the linkage (74), and a third spherical joint (73) connects the fuselage (3) to the linkage (74).

8. Aircraft according to claim 6 or 7, c h a r a c t e r i z e d in that the joint assembly (7) includes several spherical joints (71, 72, 73) arranged in a plane, particularly a plane crosswise, in particular perpendicular, to the first axis (Y).

9. Aircraft according to claim 4 or 5, c h a r a c t e r i z e d in that the joint assembly (7) includes a double cardan joint connecting the variable lift body (5) to the fuselage (3).

10. Aircraft according to claim 4 or 5, c h a r a c t e r i z e d in that the joint assembly (7) includes a crown spine connecting the variable lift body (5) to the fuselage (3).

11. Aircraft according to claim 4 or 5, c h a r a c t e r i z e d in that the joint assembly (7) includes jaw coupling connecting the variable lift body (5) to the fuselage (3).

12. Aircraft according to claim 4 or 5, c h a r a c t e r i z e d in that the joint assembly (7) includes solid body spring connecting the variable lift body (5) to the fuselage (3).

13. Aircraft according to one of the preceding 2 to 12, c h a r a c t e r i z e d in that the variable lift body (5) is fastened to the fuselage (3) using two or more joint assemblies (7) distanced apart in the direction of the first axis (Y).

14. Aircraft according to one of the claims 2 to 13, c h a r a c t e r i z e d in that the variable lift body (5) is fastened to the fuselage using exactly one joint assembly (7) and at least one bearing distanced apart from the joint in the direction of the first axis, wherein in particular the bearing allows rotational freedom of movement around the first, second and/or third axis (X, Y, Z).

15. Aircraft according to one of the preceding claims, c h a r a c t e r i z e d in that the variable lift body (5) includes an engine (51) adapted to provide thrust for the aircraft for at least one of take-off, landing, or cruising, in particular an engine (51) pivotable

in relation to the fuselage (3) between a cruising flight position in which the thrust direction (T) of the engine (51) is aligned with the longitudinal axis (X) of the aircraft (1), and a take-off/landing position in which the thrust direction (T) is angled towards the vertical axis (Z) of the aircraft (1).

16. Aircraft according to one of the preceding claims, characterized in that the variable lift body (5) includes an aerodynamic control structure, such as an aileron (55) or a control canard.

17. Aircraft according to one of the preceding claims, wherein at least one primary lift body (4), such as a canard structure and/or a wing, is stationarily attached to the fuselage (3), characterized in that the variable lift body (5) is attached to the primary lift body, wherein in particular the variable lift body (5) is arranged behind the primary lift body (4) with regard to the cruise flight direction (F).

18. Aircraft according to one of the preceding claims, characterized by further comprising another attachment (8) rotatably connecting the variable lift body (5) to the fuselage (3) around the first axis (Y) and allowing freedom of linear movement of the variable lift body (5) in the direction of the first axis (Y).

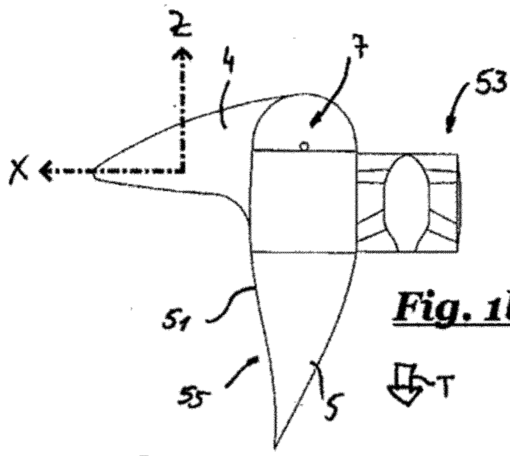

Fig. 1b

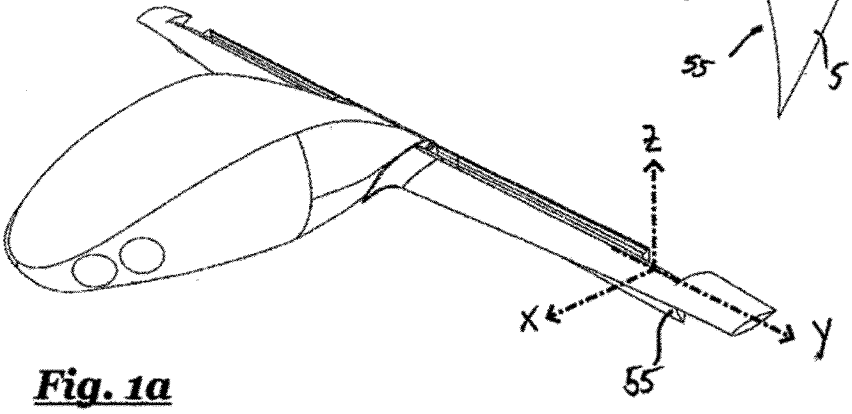

Fig. 1a

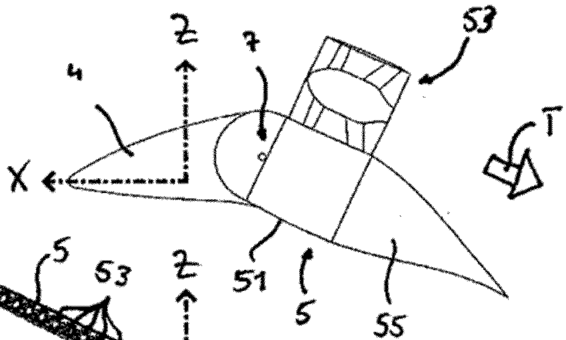

Fig. 2b

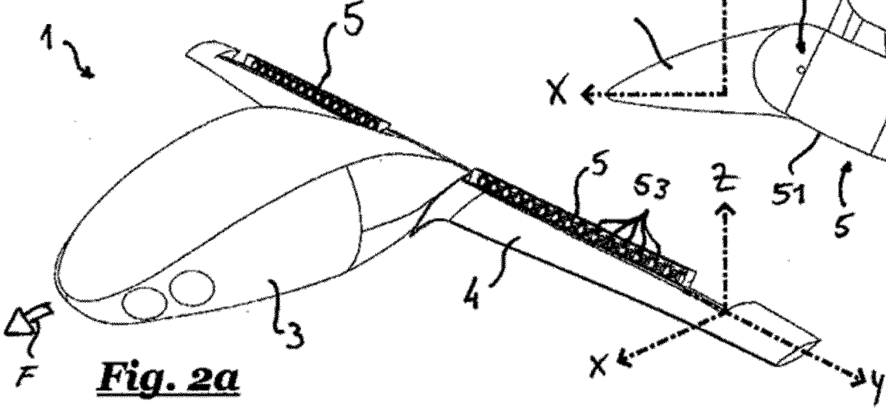

Fig. 2a

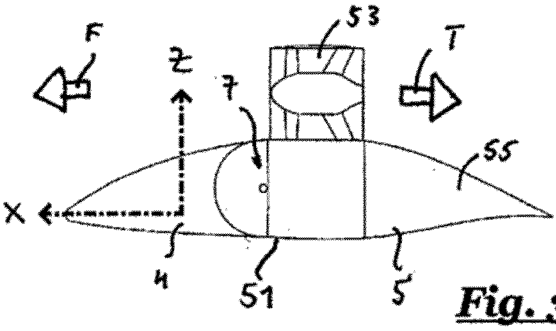

Fig. 3

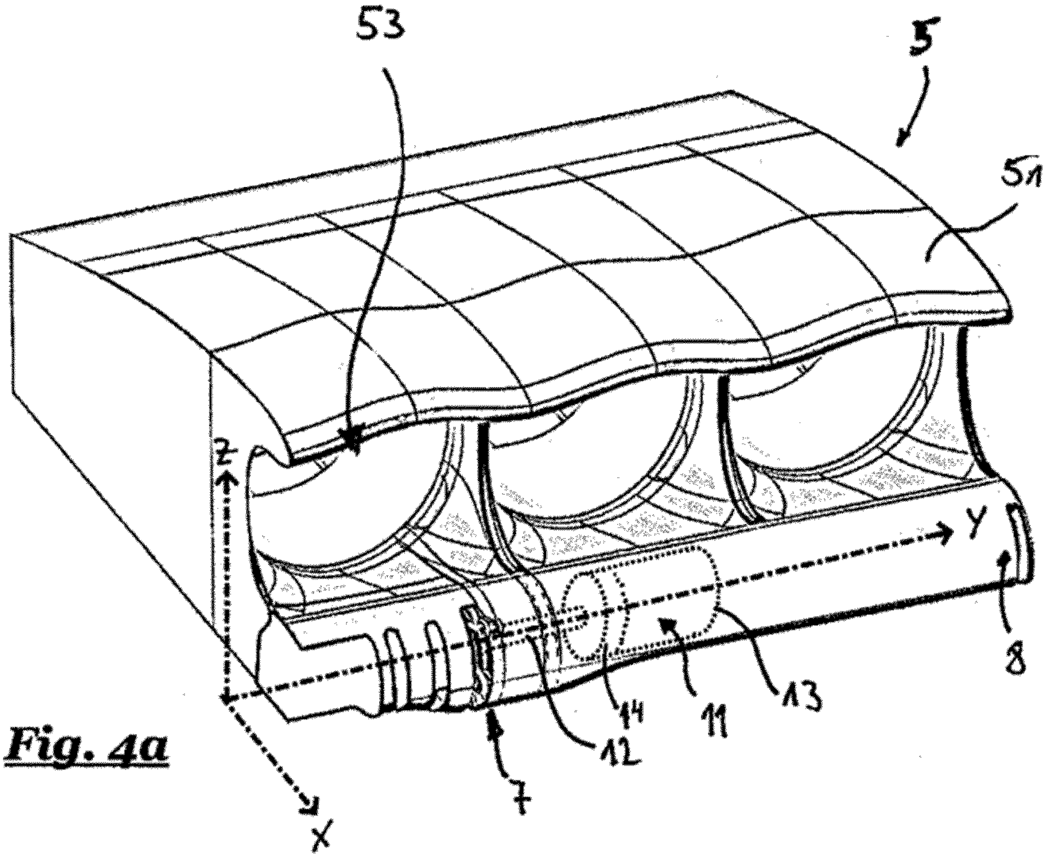

Fig. 4a

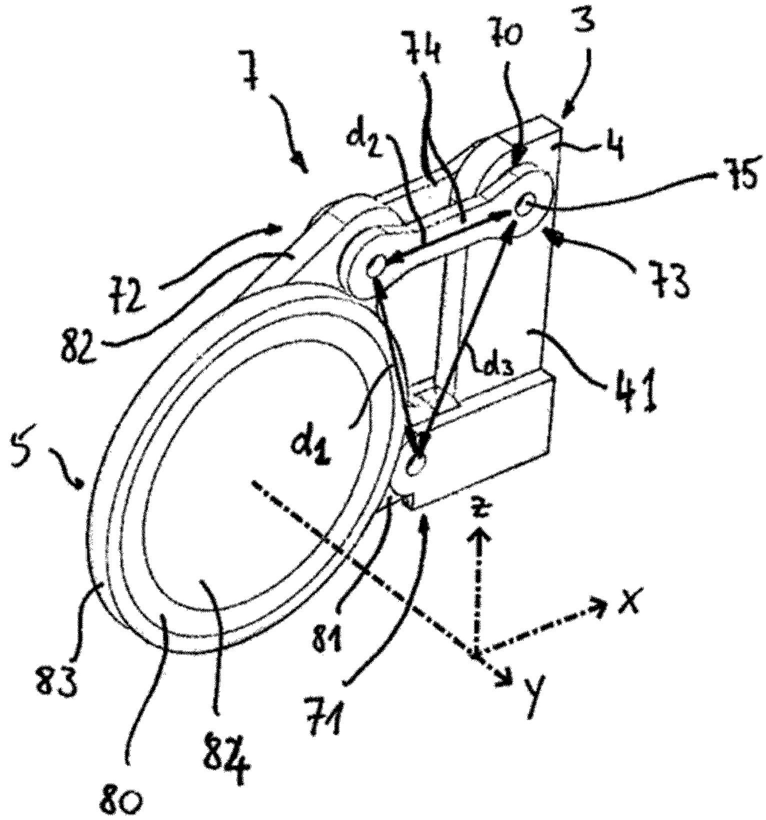

Fig. 4b

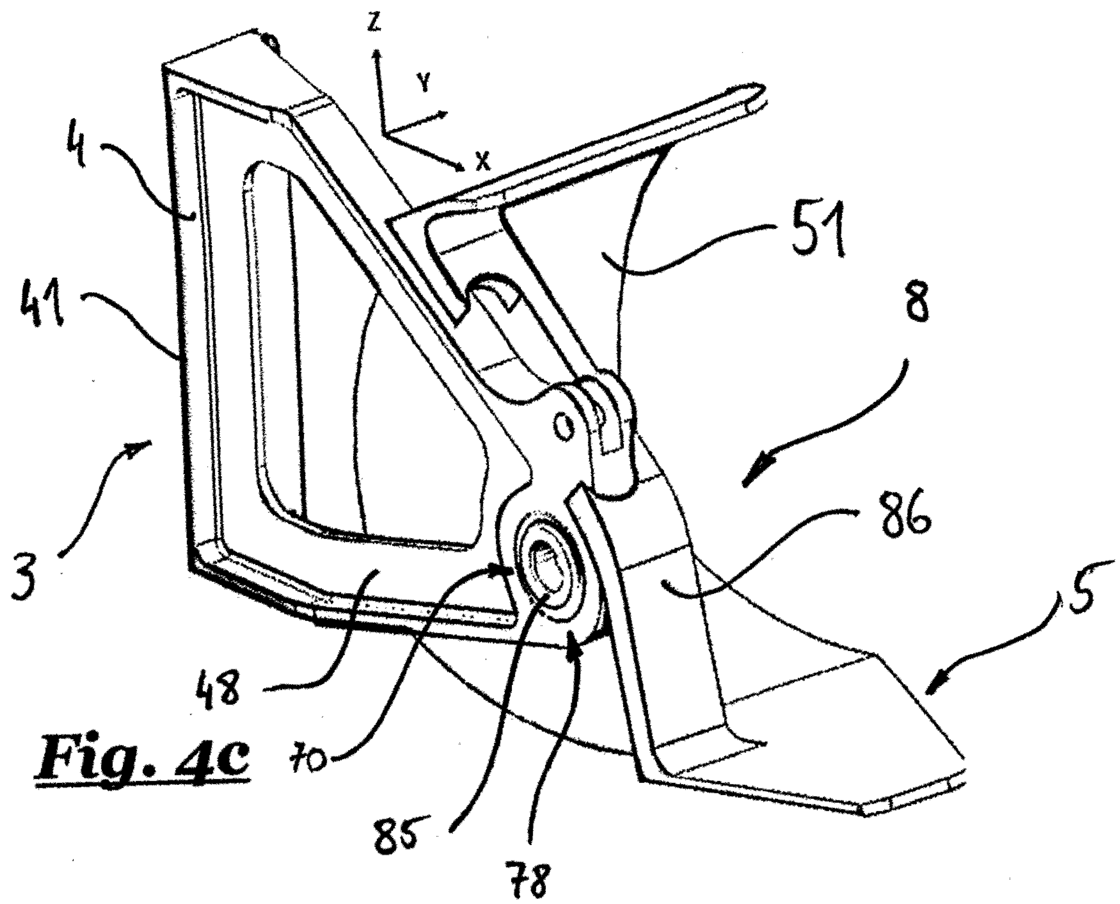

Fig. 4c

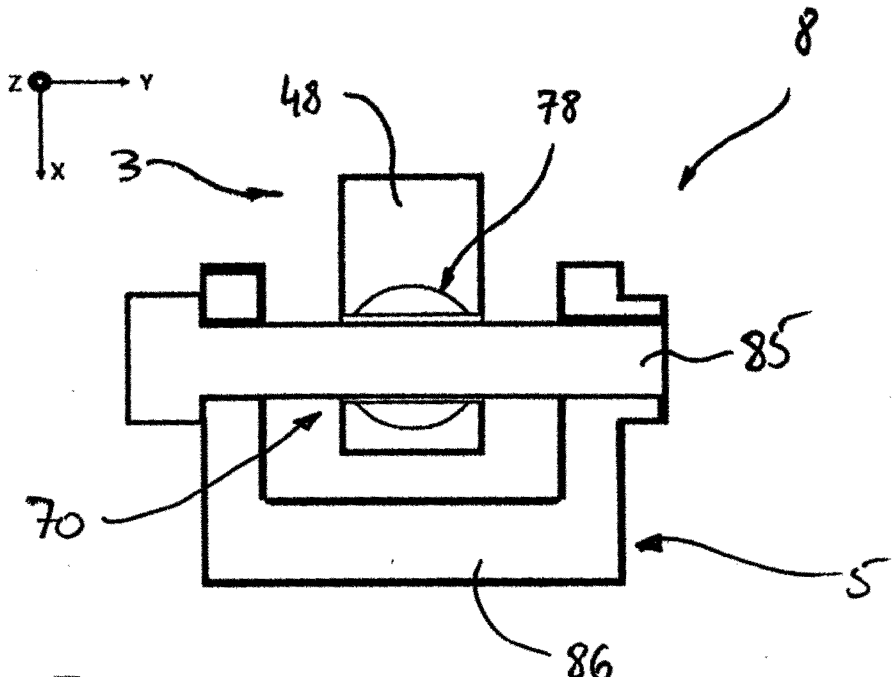

Fig. 5

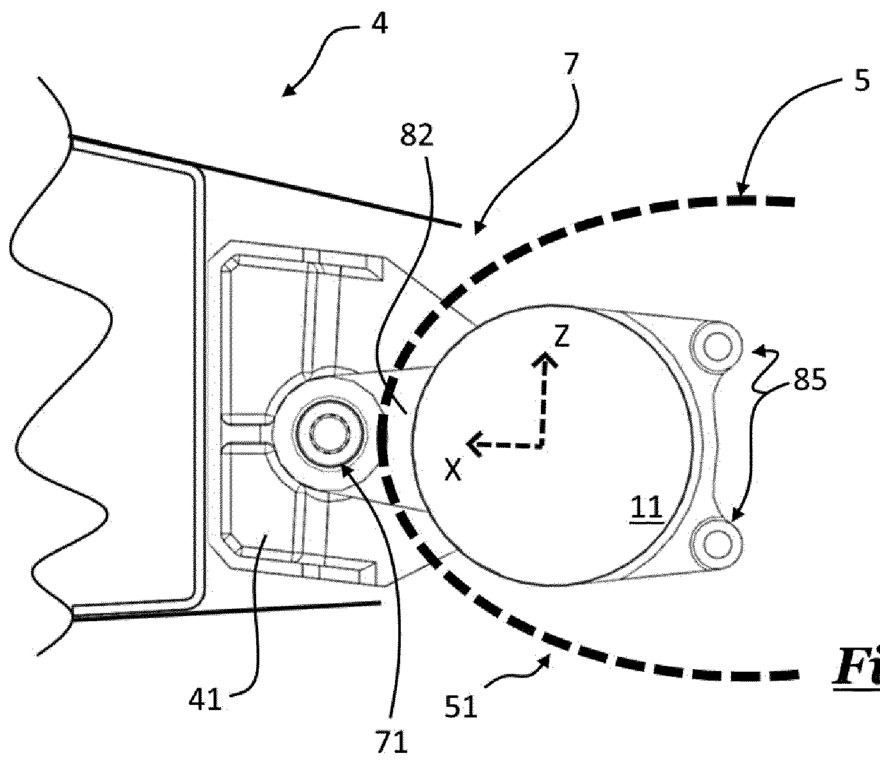

Fig. 6

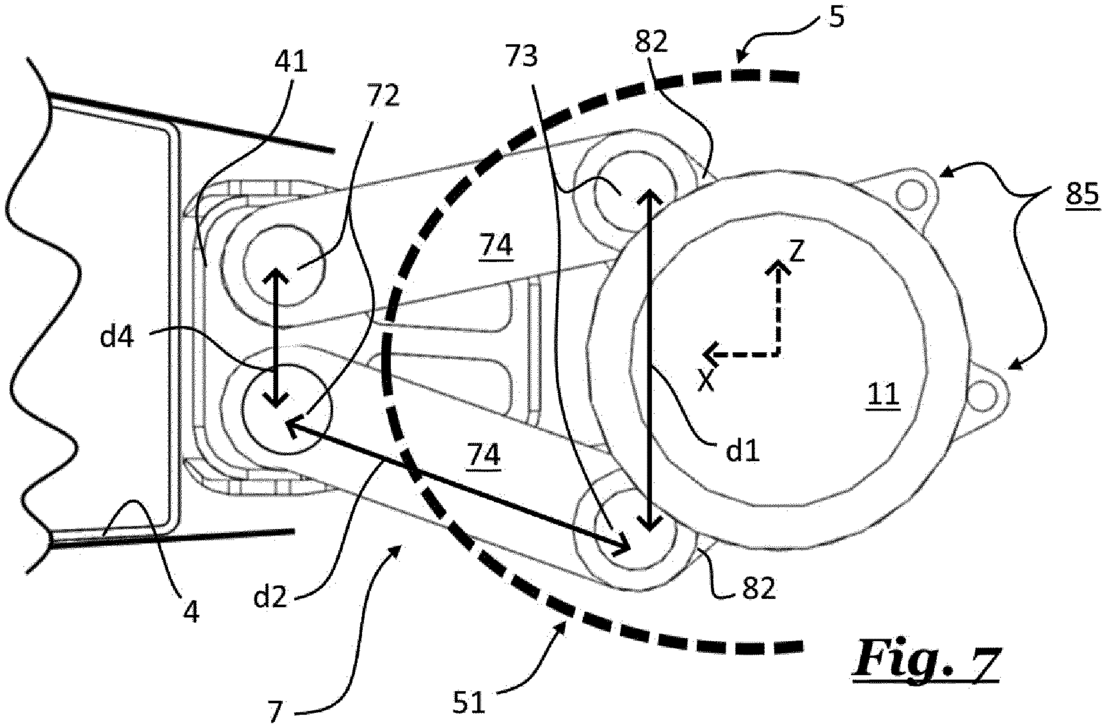

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2022/052160

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/052160

A. CLASSIFICATION OF SUBJECT MATTER
INV. B64C29/00 B64C9/16
ADD. B64D27/02 B64C11/00

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 B64D

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2009/256026 A1 (KAREM ABE [US] ET AL) 15 October 2009 (2009-10-15) paragraph [0025] - paragraph [0041]; figures 1, 3, 6, 7	1-3, 14-18 4-9, 11-13
X A	US 3 179 354 A (ALBERTO ALVAREZ-CALDERON) 20 April 1965 (1965-04-20) column 4 - column 6; figures 4-6, 9, 10	1-3, 14-18 4-9, 11-13
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[X] Further documents are listed in the continuation of Box C.

[X] 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 application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 April 2022	10/05/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Morasch, Alexander

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/052160

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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	A	paragraph [0007] - paragraph [0021]; figures 1-4, 7, 8	1-3,9, 11,12, 15,18
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	A	paragraph [0001] - paragraph [0024]; figures 1, 7, 9	1-3,9, 11,12, 15,18
9	Y	US 2 284 519 A (HALL RANDOLPH F) 26 May 1942 (1942-05-26)	4-7, 11-14, 16,17
	A	page 5 - page 7; figures 1, 2, 8, 9	1-3,8,9, 15,18
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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.
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A	paragraph [0032] - paragraph [0035]; figures 1-3	1-3,8, 11,12, 15,18

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2022/052160

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		ES 2173770 A1	16-10-2002

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-18

   An aircraft comprising a variable lift body.

1.1. claims: 1-3, 14-18

   An aircraft comprising a variable lift body, the variable lift body actuated by a rotary actor.

1.2. claims: 4-13

   An aircraft comprising a variable lift body, the variable lift body fastened to the fuselage with a joint assembly.
