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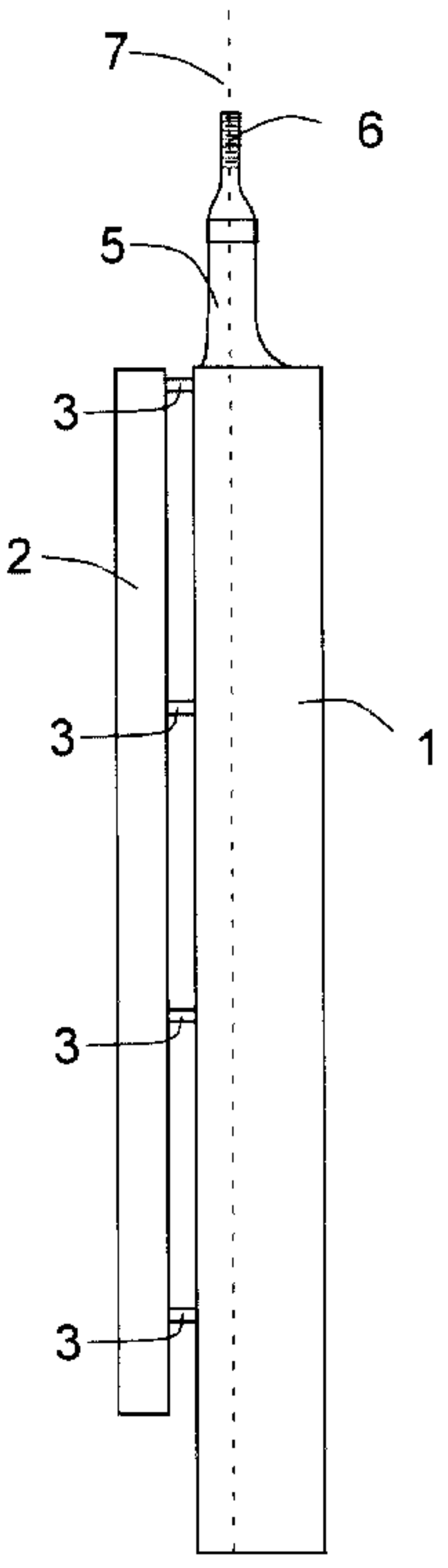
(54) Title: WIND TURBINE BLADE UNIT



(57) Abrégé/Abstract:
A blade unit assembly for applications such as wind turbines, characterized by the arrangement of a main airfoil and a smaller secondary airfoil joined by streamlined structural elements, is mounted on a rotor hub assembly using a holding spar extending from the main airfoil. A blade unit is balanced and can pivot about its holding spar longitudinal axis, and has aerodynamic static and dynamic stability that provides the blade unit with pitch angle self-adjustment capability for controlling the wind turbine rotor hub rotation speed; including initiating rotor rotation in low winds and limiting the rotor blades speed in high winds. A plurality of blade units is mounted on a rotor hub.

Abstract

A blade unit assembly for applications such as wind turbines, characterized by the arrangement of a main airfoil and a smaller secondary airfoil joined by streamlined structural elements, is mounted on a rotor hub assembly using a holding spar extending from the main airfoil. A blade unit is balanced and can pivot about its holding spar longitudinal axis, and has aerodynamic static and dynamic stability that provides the blade unit with pitch angle self-adjustment capability for controlling the wind turbine rotor hub rotation speed; including initiating rotor rotation in low winds and limiting the rotor blades speed in high winds. A plurality of blade units is mounted on a rotor hub.

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WIND TURBINE BLADE UNIT

Description

FIELD OF THE INVENTION

The present invention relates to rotating blades driven by the movement of a fluid or gas, in particular self adjusting pitch angle wind turbine blades.

BACKGROUND AND PRIOR ART

Historically, wind power was captured using windmills for the primary purpose of pumping water. Ancient windmills used sail foils and eventually rigid blade structures holding canvas material to control the amount of wind energy captured. Rotating the windmill in and out of the wind direction was also a method to control blade speed and limit damage to the windmill blades in high winds.

The slow rotating windmill blade assemblies have been replaced with modern airfoil blade profiles with predictable performances. Modern blade assemblies typically offer a lower rotor solidity, or surface area, than its ancestor's. The combination of higher relative wind speed capability and low solidity improves the wind turbine performance expectations.

Kinetic wind power increases with the cube of the wind speed. While extracting wind power in high wind conditions seems attractive, the physical limitations of the wind turbine assembly require that a system be in place to limit the resulting impact forces on the wind turbine to avoid damages.

Today, aerodynamic furling devices or hydraulic systems have been created to control the rotor blade assembly orientation relative to the wind in order to decrease the wind surface area. In other cases, mechanical brakes are used to temporarily stop the rotation of the blade assembly to avoid all possible damages. Other methods have been developed to control the rotor rotational speed such as rotor blade aerodynamic brakes, rotor blade aerodynamic stall, rotor blade ailerons, centrifugal force based control systems, and rotor blade camber or pitch control systems.

The following patents have been issued in Canada and the United States of America to propose rotor speed control solutions:

1092983	1/1981	Lippert
1120538	3/1982	Kos et al.
2193972	8/2002	Shin

4,348,156	9/1982	Andrews et al.
4,348,155	9/1982	Barnes et al.
4,352,634	10/1982	Andrews et all
4,462,753	7/1984	Harner et al.
5,456,579	10/1995	Olson
4,423,333	12/1983	Rossman
4,632,637	12/1986	Traudt
2002/0153729	10/2002	Beauchamp et al
4,339,666	7/1982	Patrick et al.
4,533,297	8/1985	Bassett
4,656,362	4/1987	Harner et al.
4,715,782	12/1987	Shimmel
5,527,152	6/1996	Coleman et al.
5,527,151	6/1996	Coleman et al.
5,161,952	11/1992	Eggers. Jr.

The solutions developed in the past mostly involved articulated components driven by mechanical actuators involving the use of electronic control systems. The resulting solutions are complex active systems.

A departure form articulated control systems consists of passive methods such as advanced composite material rotor blades that twist under certain conditions. Though rotor blades with passive pitch control characteristics have been conceived, alternative solutions offering self adjusting pitch angle alignment with the direction of the wind, in low wind and high wind conditions, have not been addressed using the inherent aerodynamic stability of a rotor blade assembly, without the essential use of articulated systems.

SUMMARY OF THE INVENTION

A main object of the present invention is the provision of a passive solution for controlling the pitch angle of wind turbine rotor blades, including initiating the pivoting of the rotor blades toward the incoming wind to initiate rotor blade rotation and to limit rotor blade rotation speed in high winds.

It is also an object of this invention to provide a rotor blade attachment means to the rotor hub, whereby the blade unit may pivot about its longitudinal axis.

The present invention is a blade unit consisting of two blades disposed in a canard type configuration providing aerodynamic static and dynamic stability, whereby both airfoils provide positive lift. This invention may be used in combination with any type of airfoil structure.

It is a main object of this invention to create a canard configured rotating blade unit assembly where the tip portion of the main airfoil forming less than 25% of the length of the blade unit assembly applies negative moment forces on the rotating blade unit about the longitudinal pivoting axis of the blade unit, given that the main airfoil lift component is located between the main airfoil longitudinal axis and the main airfoil trailing edge. In high wind situations, a relative wind speed exceeding the rotating blade unit operating speed characterized by its aerodynamic static stability characteristics will cause the pivoting of the blade unit leading edges upwind and limit the rotor blade rotation speed due to the incremental lift acting on the tip portion of the main airfoil.

It is an object of this invention to locate the smaller secondary airfoil ahead of the main airfoil leading edge and upwind in a canard configuration. The smaller airfoil may be located below or above the main airfoil chord axis, or the main airfoil chord axis. The positioning of the smaller canard airfoil is dependent on the designed operating rotational speed of the rotating blade unit as to avoid airflow interference of the secondary airfoil on the main airfoil. The positive incidence angle of the small airfoil relative to the main airfoil chord axis combined with the proper combination of airfoil profile will ensure the canard airfoil will stall before the main airfoil in a gust wind situation and therefore ensure the blade assembly will tilt into the wind to create lift.

It is also an object of this invention to make the radius of the main airfoil of a blade unit extend outwardly beyond the secondary canard airfoil radius. In this particular configuration, the blade unit assembly operates at a designated rotational speed which, when exceeded, causes the section of the main airfoil to augment the main airfoil lift component more rapidly than that of the secondary canard airfoil, thus creating a negative moment on the blade unit therefore reducing its pitch angle and limiting its rotational speed.

The blade unit attachment of the subject invention consists of a spar threaded at one extremity with a counterpart assembly on the hub. The center line of the blade unit holding spar longitudinal axis is aligned with the main blade aerodynamic center usually located at the 25% chord.

The blade unit is prevented from completely rotating about its longitudinal axis using restraining devices limiting the pivoting to no more than 90 degrees to ensure the resulting total lift from the blade unit make the rotor assembly in the desired rotational direction.

In addition, the blade assembly is statically weight balanced around the holding spar as to ensure gravity forces do not affect blade unit pitch angle during its rotation. This is accomplished with the selection of proper materials, weight distribution and use of counterbalancing weights located on the blade unit holding spar near the hub assembly.

The said blade unit generates lift when the incoming wind causes the blade unit to pivot about the blade unit longitudinal axis, to point its leading edges into the wind, at which point a sufficient wind speed causes the blade units to start rotating around the rotor hub. As the relative wind direction changes with the increased rotor speed, and wind speed increases, the blade unit reaches a rotation speed predetermined by the proportions and dimensions of the bade unit assembly, and determined by the power extracted through the rotor hub, for turning a electrical power generator, for example. Increases in wind speed increase the power transferred to the rotor blades which will accelerate beyond the predetermined blade unit speed if power is not extracted. As a blade unit moves beyond its designed rotation speed, the additional lift created at the tip of the main airfoil, in the area of the tip of the main airfoil 1 which extends beyond the radius of the secondary airfoil, will cause the blade unit to pivot into the wind and slow it down.

In another aspect of the present invention, the wind turbine blade assembly consists of a plurality of blade units attached similarly to the rotor hub assembly. The blade units may be linked with a common pitch control assembly apparatus located on the blade unit spars to ensure all blades operate with a common pitch angle.

In an alternative construction of the blade unit, the blade unit is twisted as to reduce the pitch angle of the tip of the blade unit, to reduce the load at the tip of the blade unit in rotation, the said load created by the higher relative wind speeds toward the tip of the blade.

BRIEF DESCRIPTION OF THE DRAWINGS

The benefits, advantages and characteristics illustrated in the drawings described below form part of the specification of this invention.

Figure 1 is a side view of a canard configuration blade unit.

Figure 2 is a plan view of a canard configuration blade unit.

Figures 3.a-3.b present views of the general location of the counterweight and pivoting restraining device on the blade unit holding spar, as well of a view of the blade unit holding spar threaded extremity and lateral force bearing assembly matching the sliding counterparts fixed on the horizontal axis wind turbine hub assembly.

Figures 4.a-4.c are schematic views of alternative blade unit canard configurations contributing to the blade self-adjusting characteristics aimed by this invention.

Figures 5a-5d show a side view of an alternate canard configuration of the blade unit with the secondary airfoil positioned above the main airfoil chord axis.

WIND TURBINE BLADE UNIT

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In the basic embodiment of the invention, the arrangement of the blade unit depicted in part in FIG. 1, consists of a positive camber main airfoil 1 on which a symmetrical secondary airfoil 2 is mounted using at least two streamlined structural elements 3 distributed along the length of the secondary airfoil 2. The airfoils 1 and 2 consists of sturdy but flexible structures made of lightweight materials such as fiber reinforced composite materials, wood or aluminum with fatigue resistant properties.

In the preferred embodiments, the secondary airfoil 2 is located ahead of the main airfoil 1 in a canard configuration. More specifically, the trailing edge of the secondary airfoil 2 shown in FIG. 1 is located ahead of the leading edge of the main airfoil 1 along the main airfoil chord axis 10.

FIG.1 shows the secondary airfoil 2 located below the main airfoil chord axis 10 as to not interfere with the main airfoil air flow in the direction depicted by the prominent relative wind direction 17. The operating relative wind direction 17 is determined by the aerodynamic characteristics of the assembled blade unit.

The streamlined structural elements 3 depicted in FIGS 1-5 are rigid structures made of vibration resistant metal or fiber reinforced composite material beams with an aerodynamic external profile in the direction perpendicular to the longitudinal axis of the main airfoil 1 and parallel to the main airfoil chord axis 10. The structural elements 3 are fastened to reinforced bottom surface areas of the main airfoil or are fastened to the main airfoil rib structures using locking type fasteners. At the other end, the structural elements 3 are fastened to the thinner secondary airfoil 2 core structure using locking type fasteners. Structural elements 3 maintain a constant distance between the main airfoil aerodynamic center and the secondary airfoil aerodynamic center. The structural elements 3 also counteract the lift forces and centrifugal forces on the secondary airfoil 2.

In another embodiment configuration depicted in FIG 5, the secondary airfoil 2 is positioned above the main airfoil chord axis 10. In this canard configuration, the structural elements 3 are fastened to the top surface area of the main airfoil 1, and are fastened to the bottom surface of the secondary airfoil 2 to limit airflow interference on the main airfoil 2.

In the preferred embodiment of this invention, the canard configuration features aerodynamic static stability characteristics whereby specific physical proportions are respected. In particular, the secondary airfoil 2 shown in FIG 1 has a positive incidence pitch 13 defined by the angle between the main airfoil zero lift line direction 11 and the secondary airfoil zero lift line direction 12 which consequently is the same axis as the secondary airfoil chord axis for the preferably symmetrical secondary airfoil 2.

The said blade unit moves in a plan of rotation 14 shown in FIG. 1 and FIG. 5 around a rotor hub in the direction 15. The said blade unit pivots about its longitudinal axis 7 depicted in FIG. 2, located between the main airfoil leading edge and the aerodynamic center of the main airfoil 2 depicted by the aerodynamic center line 16 located at approximately 25% of the main airfoil chord from the main airfoil leading edge.

FIG. 2 shows the preferred arrangement of the blade unit and presents a key aspect of the present invention; the main airfoil 1 extending further outward than the said secondary airfoil 2. The area of the tip of the main airfoil 1 which extends beyond the radius of the secondary airfoil 2 causes the blade unit to pivot into the wind and slow it down when the relative wind speed increases beyond the blade unit characteristic rotation speed.

In another aspect of the present invention, a blade unit holding spar 5 extending from the root of the main airfoil is secured firmly to the main airfoil as shown in FIG. 2. In the preferred embodiment, the holding spar 5 is an extension and forms part of the main airfoil 2. The blade unit holding spar 5 provides a means to connect the said blade unit to the wind turbine hub assembly 26 mounted on the rotor hub 27, as shown in FIG 3.b.

In yet another aspect of the present invention, the said blade unit holding spar 5 shown in FIG.2 includes a threaded extremity 6 that screws smoothly in a matching threaded counterpart 24 mounted on the horizontal axis wind turbine hub assembly 26 depicted in FIG. 3.b. The said holding spar threaded extremity 6 has machined low pitch threads providing a rotating sliding grip on its matching counterpart 24 on the rotor hub assembly 26. The threaded extremity 6 of the holding spar 5 is preferably aligned and centered with the main airfoil aerodynamic center line 7 depicted in FIGS. 2 and 3.b. The said holding spar threaded extremity 6 is complemented by a lateral force bearing 23 located between threaded extremity 6 of the said holding spar 5 and the root of the main airfoil 1, the said force bearing 23 matching a sliding counterpart 25 fixed on the wind turbine hub assembly 26. A ring 28 secures the bearing 23 in position on the holding spar 5.

In yet another aspect of the present invention, the thread direction of the said threaded extremity 6 is opposite to the direction of rotation of the rotor blades on the rotor hub axis when observing the wind turbine from a upwind position to cause, to create a tendency for the centrifugal forces on the blade unit to pivot the blade unit upwind.

FIGS. 3a and 3.b depict mechanisms which are mounted to the blade unit holding spar 5. In another aspect of the present invention, the blade unit holding spar 5 shown in FIGS. 3a and 3.b comprises a counterweight 20 mounted on and secured to a ring 28 fastened to the holding spar 5, to balance the said blade unit weight about its longitudinal axis 7.

In another aspect of the present invention, the said blade unit holding spar 5 shown in FIG. 3.a further comprises a blade unit pivoting restraining device 21 to limit the operation of the said blade unit within a predetermined pitch angle range of less than 90 degrees about the longitudinal axis of the said blade unit to prevent the rotor blades from rotating in the opposite direction. As an improvement to the blade unit pivoting restraining device 21, the said restraining device 21 is also a shock absorber type strut linked to a rod mounted perpendicularly on the holding spar 5 to provide functions such as pitch angle range stopper, rotation movement absorber, and a low wind blade pitch position stabilizer normally extended to keep the blades pitch angle to the maximum in winds below the cut-in wind speed. The other end of the shock absorber pivoting restraining device 21 is attached to the rotor hub assembly holding point 22 shown in FIG. 3.b.

FIGS. 4.a to 4.c show alternate blade unit canard configurations which provide improvements to this invention. The configurations present aerodynamic characteristics that augment the negative moment forces of the blade unit in high relative winds to cause the pivoting of the blade unit into the wind when the relative wind speeds along the blade unit exceed the designed values. FIG 4.a shows a secondary airfoil 31 with a longitudinal axis 30 tilting toward the main airfoil tip and parallel to the main airfoil chord axis. In an alternate embodiment depicted in FIG 4.b, the holding spar axis 34 tilts laterally toward the leading edge of tip of the main airfoil at an angle no greater than 10 degrees. In this configuration, the secondary airfoil 33 is permitted to extend the length of the main airfoil as to create additional blade unit lift capacity. In yet another embodiment depicted n FIG.4.c, the secondary airfoil 36 is tapered at its tip. In this configuration, the secondary airfoil 36 is permitted to extend the length of the main airfoil as to create additional blade unit lift capacity.

CLAIMS

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A wind turbine blade unit, comprising a main airfoil, a secondary airfoil attached to the main airfoil using streamlined structural elements, and a blade unit holding spar mounted on the horizontal axis wind turbine hub assembly for pivotal movement a longitudinal axis of the blade unit.

2. The wind turbine blade unit of claim 1, wherein the said secondary airfoil is mounted in a canard configuration ahead of the leading edge of the said main airfoil and oriented in the general direction of the main airfoil longitudinal axis as to establish aerodynamic static and dynamic stability to the said rotating blade unit.

3. The wind turbine blade unit of claim 2, wherein the said secondary airfoil has a positive incidence angle relative to the said main airfoil chord axis as to create positive lift during operation of the said blade unit.

4. The wind turbine blade unit of claim 3, wherein the said main airfoil extends further outward from the rotor hub than the said secondary airfoil to cause the blade unit to pivot into the wind and slow down when the relative wind speed increases beyond the blade unit characteristic rotation speed.

5. The wind turbine blade unit of claim 1, wherein the said blade unit holding spar comprises a threaded extremity matching a threaded counterpart fixed on the said wind turbine hub assembly.

6. The wind turbine blade unit of claim 5, wherein the thread direction of the said threaded extremity is opposite to the direction of rotation of the rotor blades on the rotor hub axis when observing the wind turbine from a upwind position to cause, to create a tendency for the centrifugal forces on the blade unit to pivot the blade unit upwind.

7. The wind turbine blade unit of claim 5, wherein the said blade unit holding spar further comprises a lateral force bearing means located between threaded extremity of the said holding spar and the root of the blade unit, the said force bearing means matching a bearing counterpart fixed on the said wind turbine hub assembly, to allow a rotational and longitudinal sliding movement on the said holding spar.

8. The wind turbine blade unit of claim 1, wherein the said blade unit holding spar comprises a pivoting restraining device for limiting the pivoting of the blade unit within a pitch angle range of less than 90 degrees about the longitudinal axis of the said blade unit to prevent the rotor blades from rotating in the opposite direction.

9. The wind turbine blade unit of claim 1, wherein said blade unit holding spar comprises a counterweight to balance the blade unit weight about the blade unit longitudinal axis.

10. The wind turbine blade unit of claim 3, wherein the secondary airfoil longitudinal axis is tilted toward the main airfoil in the plan of rotation of the rotor blades to augment the negative moment forces of the blade unit in high relative winds.

11. The wind turbine blade unit of claim 3, wherein the blade unit holding spar longitudinal axis is tilted toward the tip of the secondary airfoil in the plan of rotation of the rotor blades to augment the negative moment forces of the blade unit in high relative winds.

12. The wind turbine blade unit of claim 3, wherein the secondary airfoil tip section has smaller dimensions and lift coefficient than those at the root of the said secondary airfoil to augment the negative moment forces of the blade unit in high relative winds.

WIND TURBINE BLADE UNIT

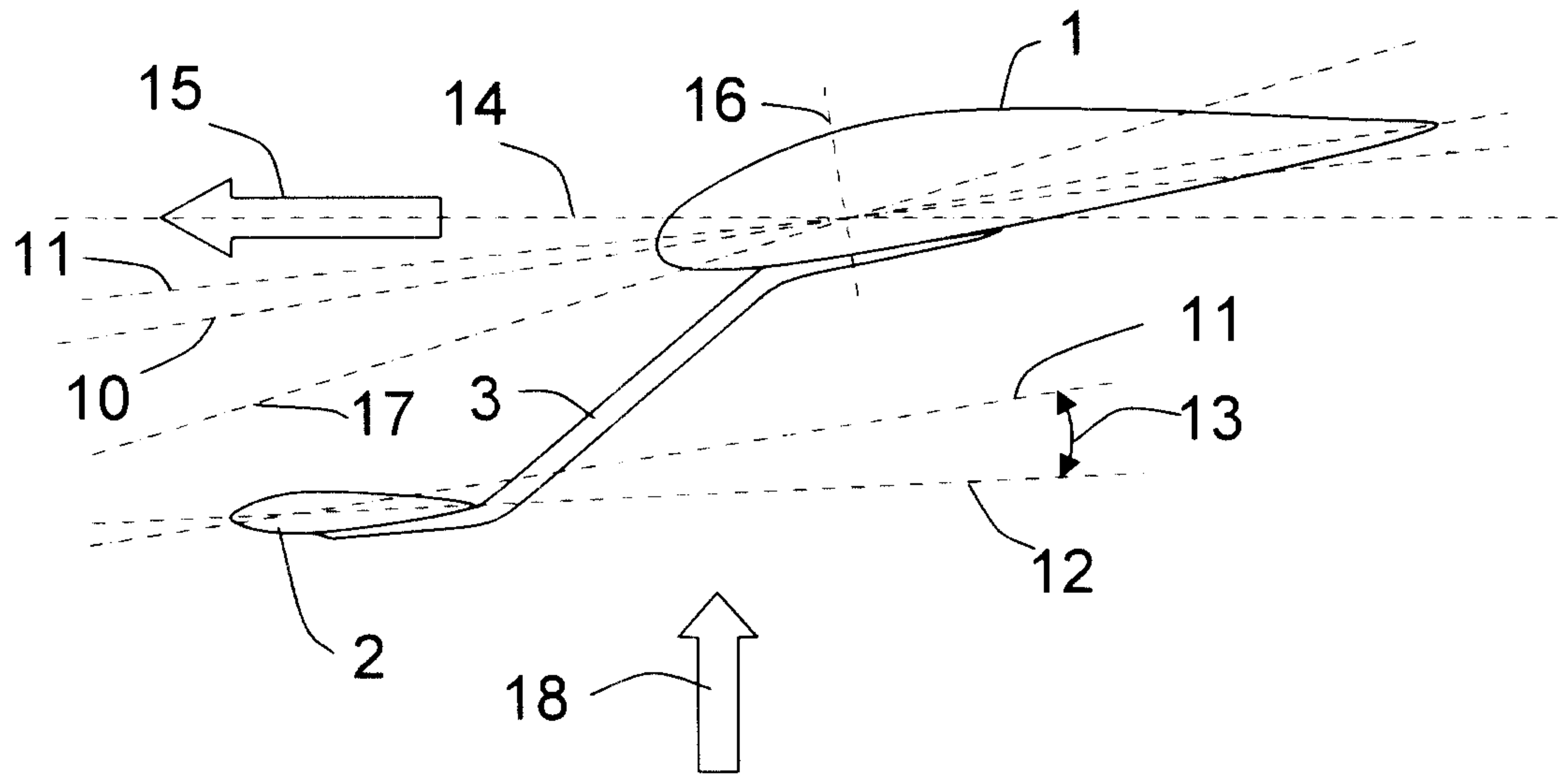


FIG. 1

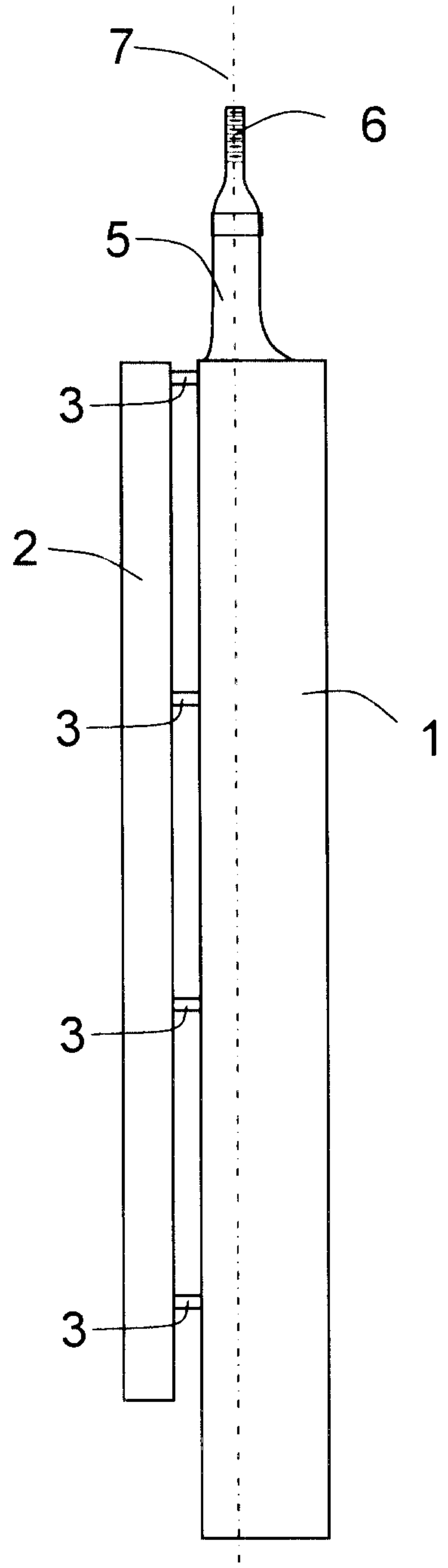


FIG. 2

WIND TURBINE BLADE UNIT

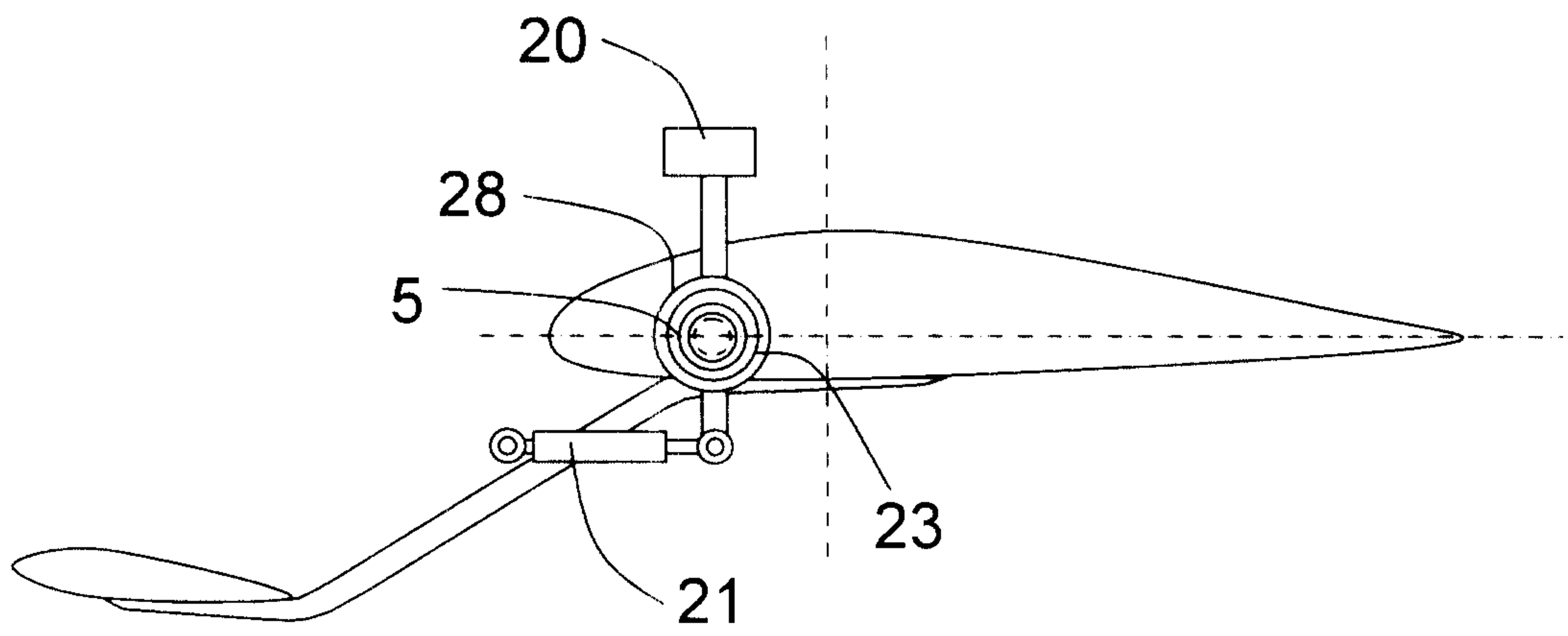


FIG. 3.a

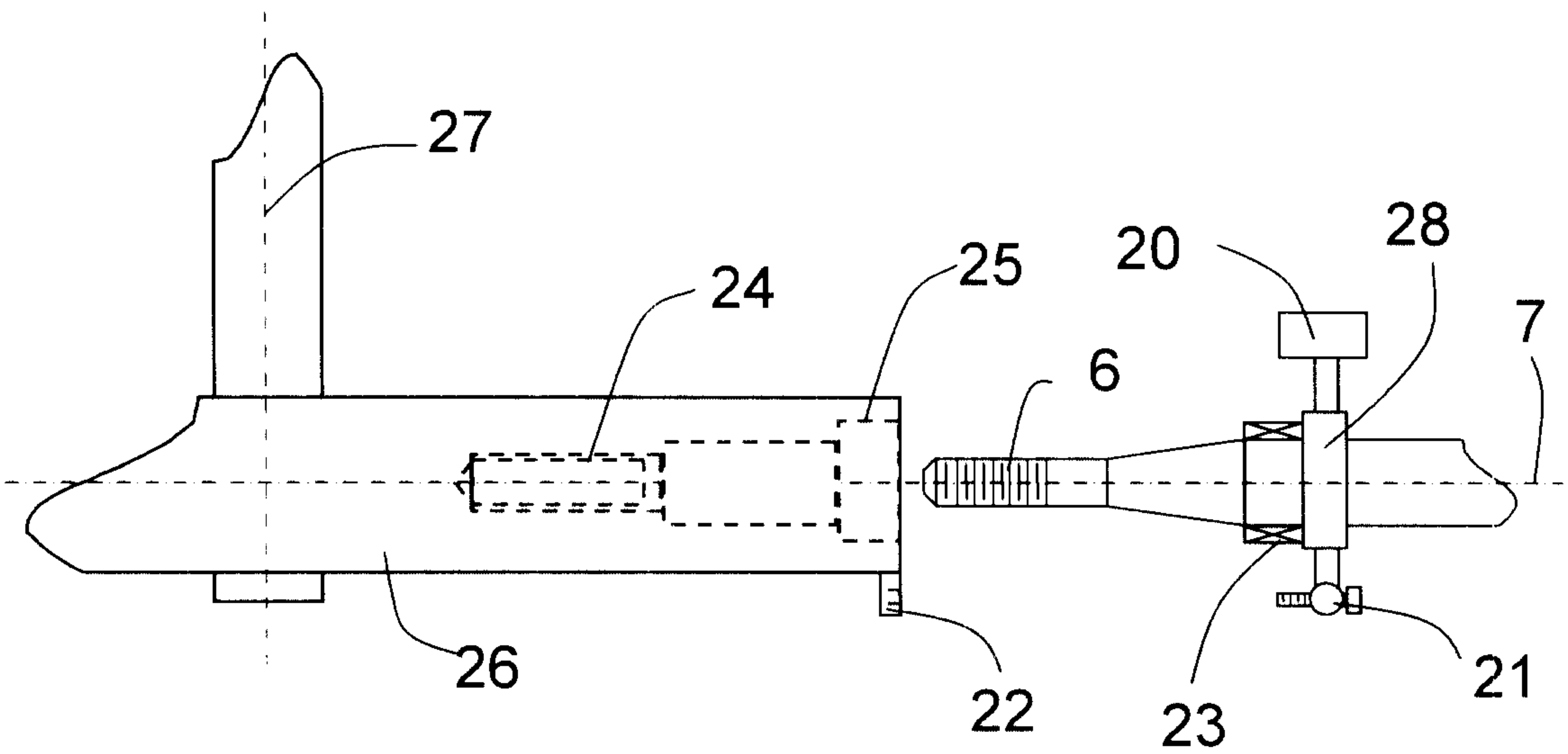


FIG. 3.b

WIND TURBINE BLADE UNIT

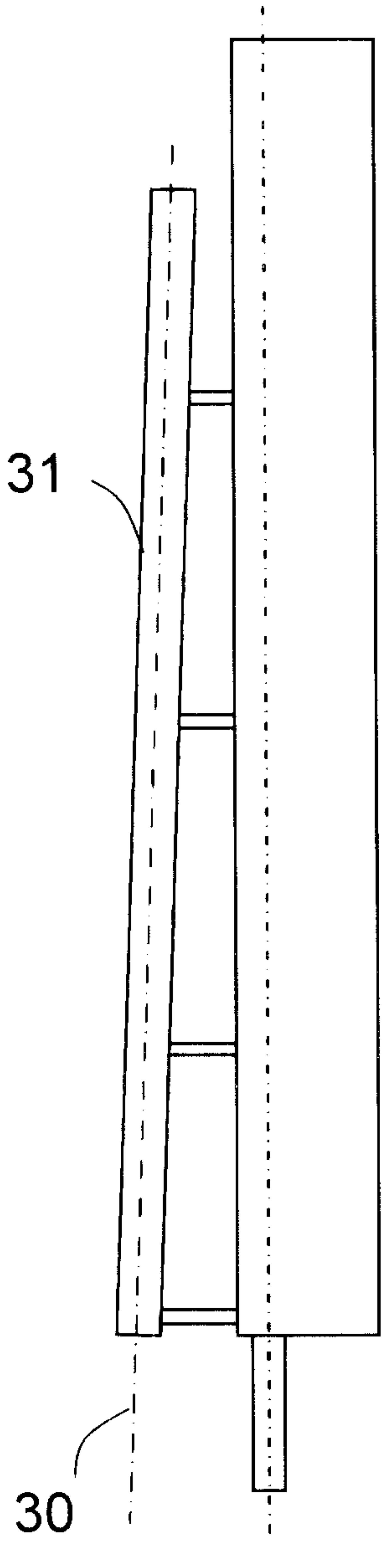


FIG. 4.a

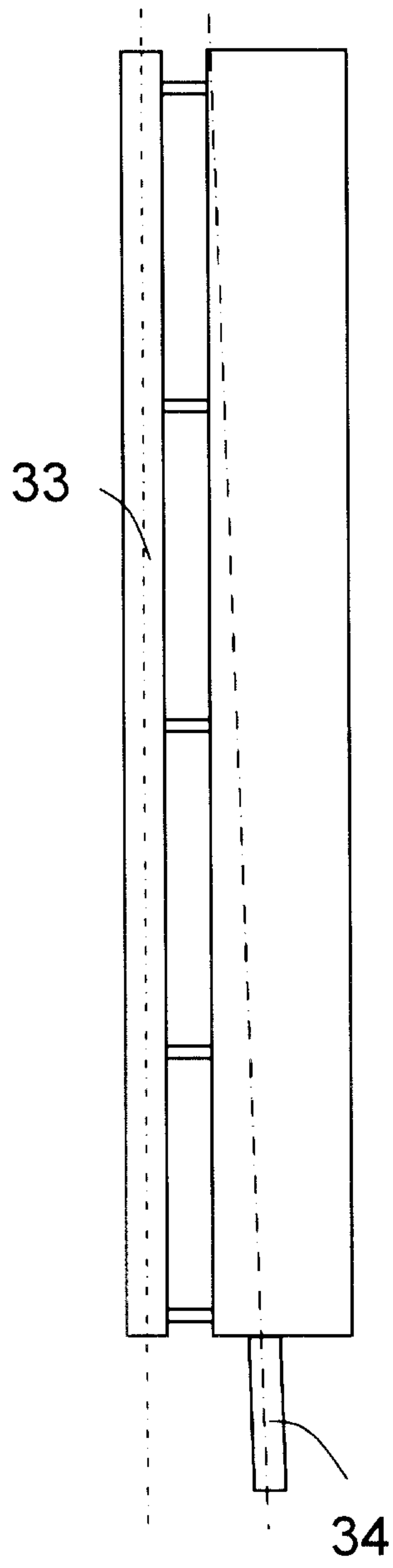


FIG. 4.b

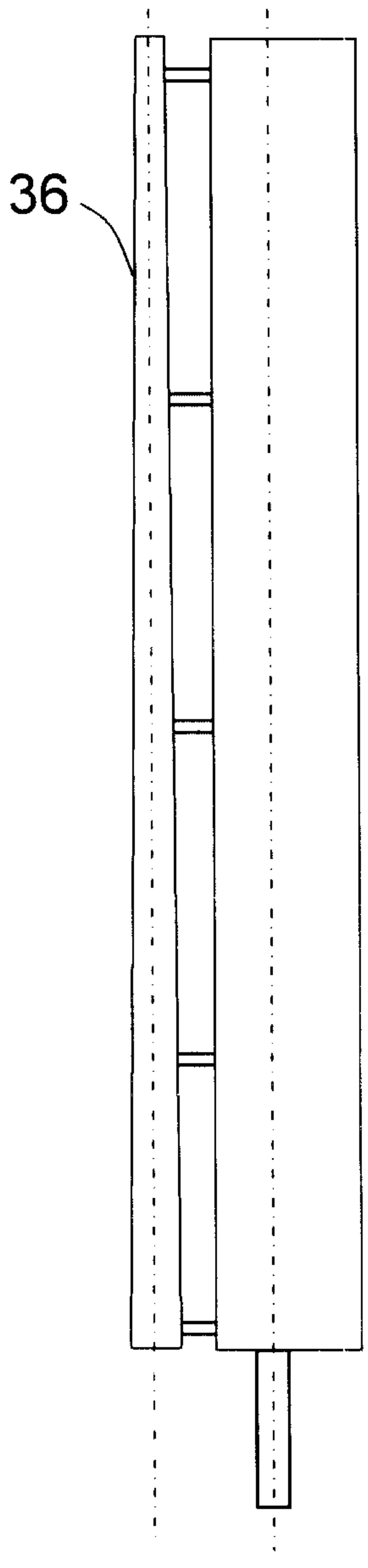


FIG. 4.c

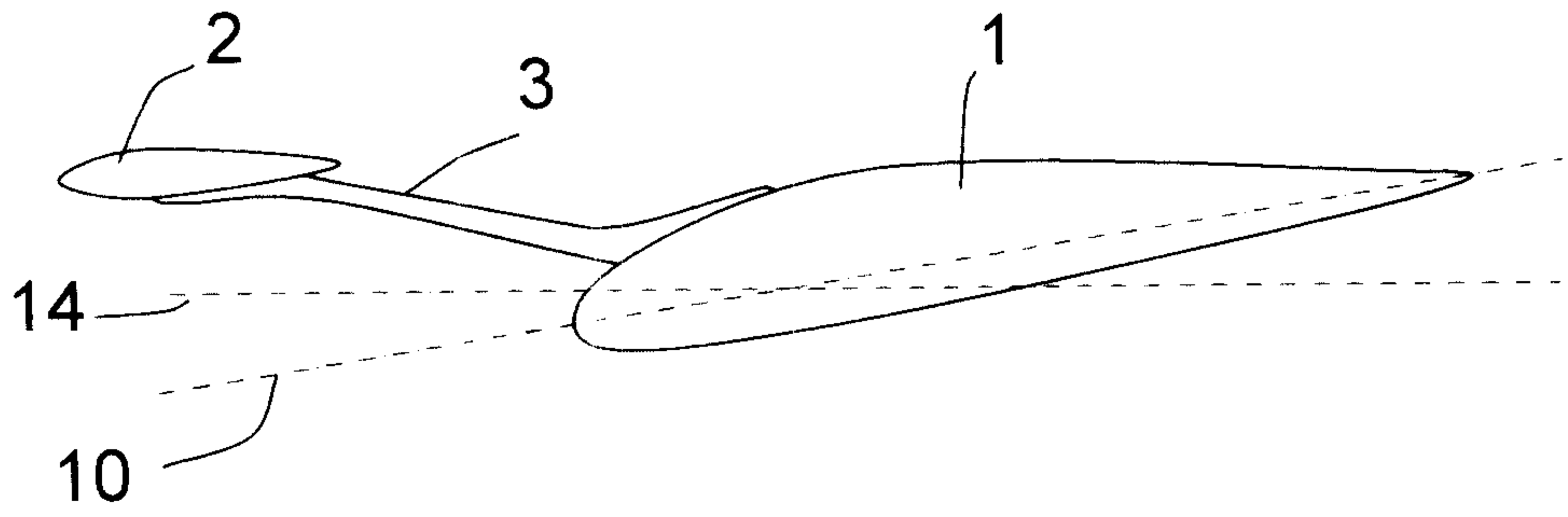
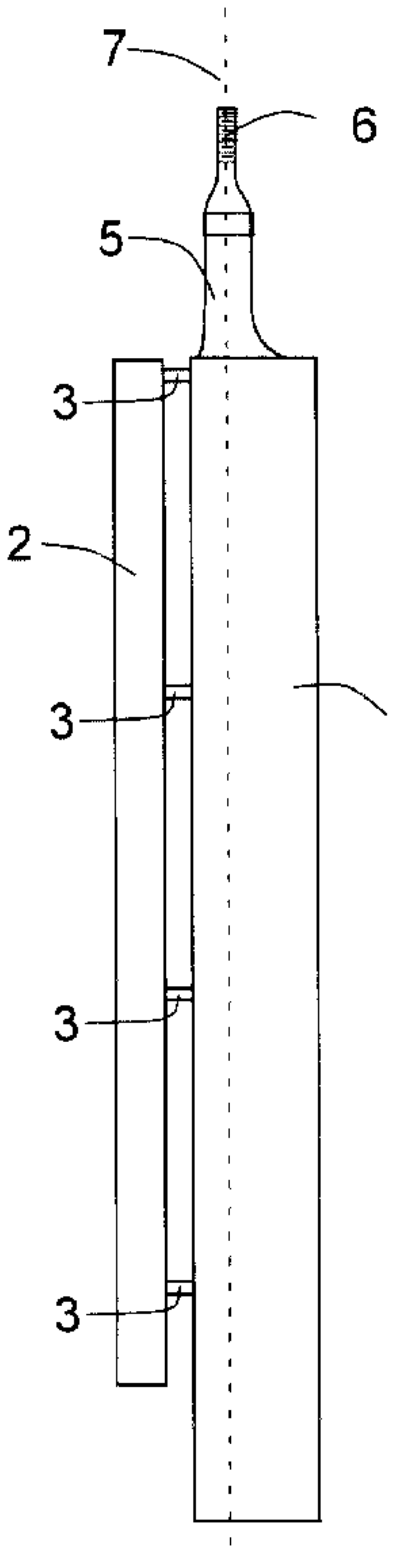


FIG. 5



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