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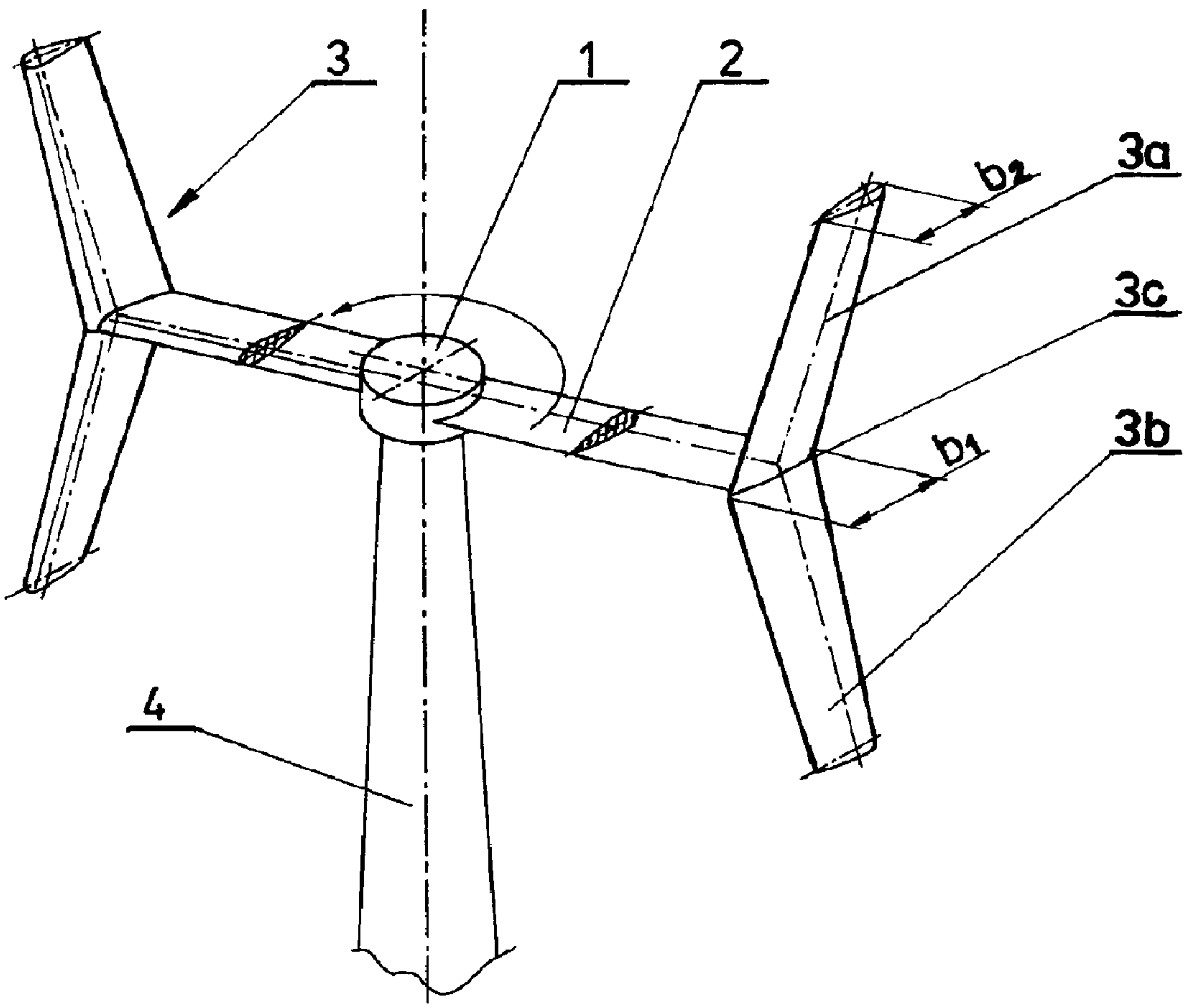
(54) Titre : ROTOR D'EOLIENNE AVEC AXE DE ROTATION VERTICAL
(54) Title: WIND TURBINE ROTOR WITH THE VERTICAL ROTATION AXIS



(57) Abrégé/Abstract:
The rotor has, connected with the hub (1), at least two horizontal supports (2) on the ends of which are rotor blades (3) of a symmetrical and concavo-convex aerodynamic profile with the chord lengths (b1, b2) and the thickness of the profile diminishing

(57) **Abrégé(suite)/Abstract(continued):**
towards both wing ends (3a, 3b). The upper wing (3a) and the lower wing (3b) of the rotor blade (3) are radially deflected from the central zone (3c) outwards. The length of the chords (b2) of the profile of both wing ends (3a, 3b) and the chord length (b1) in the central zone (3c) are approximately inversely proportional to the radii of its location in relation to the axis of the rotor's rotation. The deflecting angle of the lower wing (3b) can be greater than the deflecting angle of the upper wing (3a) or the length of the lower wing (3b) can be greater than the length of the upper wing (3a). The specification of the rotor gives a uniform intensity of consuming wind power at the length of the wings and generally in the support only tensile stress is generated while the hazard of flutter is practically eliminated.

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(54) Title: WIND TURBINE ROTOR WITH THE THE VERTICAL ROTATION AXIS

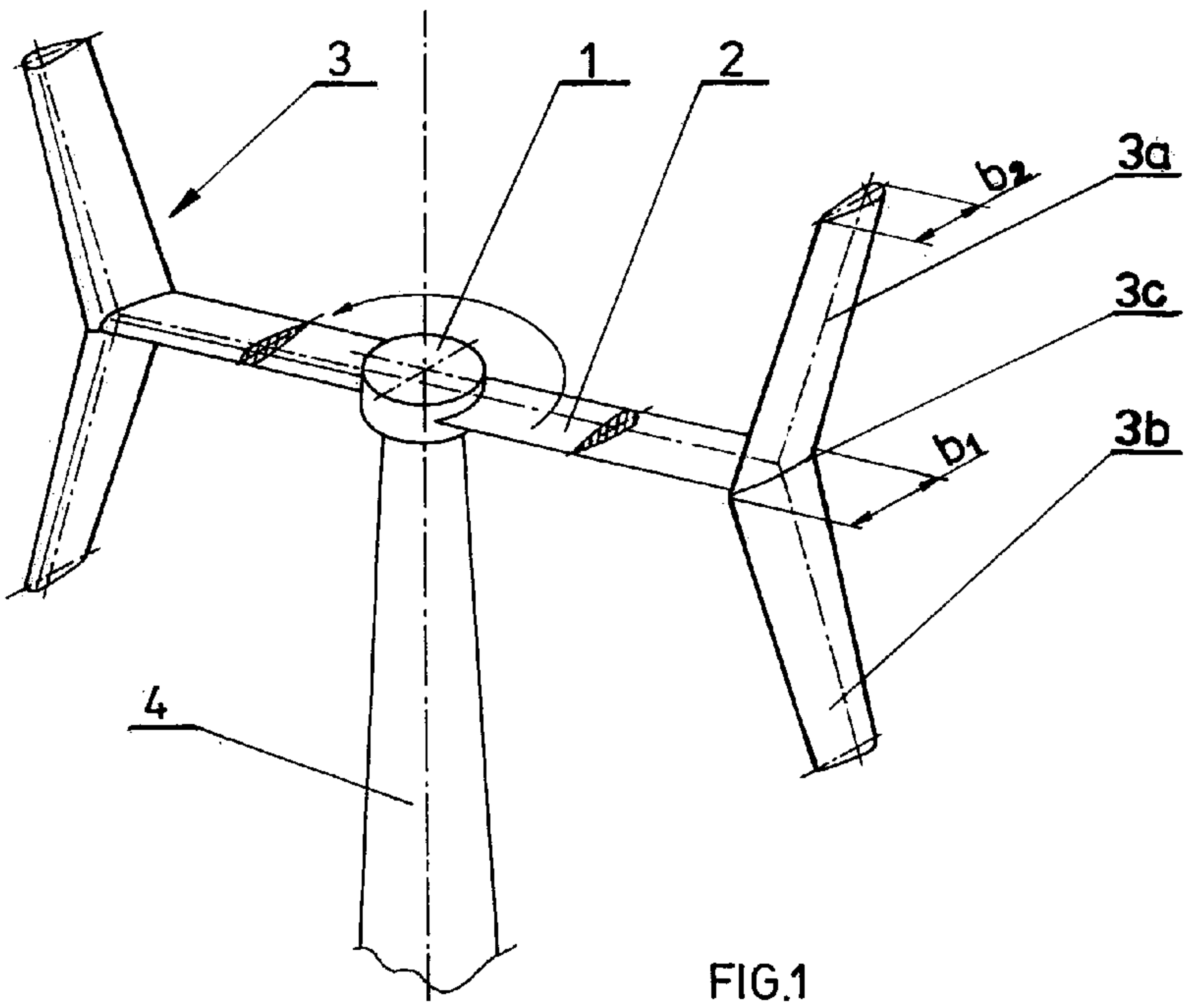


FIG.1

(57) Abstract: The rotor has, connected with the hub (1), at least two horizontal supports (2) on the ends of which are rotor blades (3) of a symmetrical and concavo-convex aerodynamic profile with the chord lengths (b1, b2) and the thickness of the profile diminishing towards both wing ends (3a, 3b). The upper wing (3a) and the lower wing (3b) of the rotor blade (3) are radially deflected from the central zone (3c) outwards. The length of the chords (b2) of the profile of both wing ends (3a, 3b) and the chord length (b1) in the central zone (3c) are approximately inversely proportional to the radii of its location in relation to the axis of the rotor's rotation. The deflecting angle of the lower wing (3b) can be greater than the deflecting angle of the upper wing (3a) or the length of the lower wing (3b) can be greater than the length of the upper wing (3a). The specification of the rotor gives a uniform intensity of consuming wind power at the length of the wings and generally in the support only tensile stress is generated while the hazard of flutter is practically eliminated.

WO 2009/099344 A2

WIND TURBINE ROTOR WITH VERTICAL ROTATION AXIS

The invention is a wind turbine rotor with a vertical rotation axis, used in the turbines applying the Darrieus' principle while processing the wind energy into the mechanical energy of the rotation movement.

Solutions of turbine rotors with the vertical rotation axis that are known e.g. from the patent descriptions US 4264279 and US 4430044 have, connected with the hub of the drive shaft, at least two horizontal supports with vertically mounted rotor blades on the ends.

Rotor blades have mostly a symmetrical airfoil and are connected with the support in the center zone of their height, with the division of the blade into the upper wing and the lower wing. During the rotor movement exerted by the wind pressure apart from the driving aerodynamic force, there is also centrifugal force. Both forces act in the centres of the mass of two wings. In the middle of the trajectory of the blade rotation movement, the aforementioned forces are directed to the same direction – resulting in the longitudinal deformation of the wings and high bending stress in the connection zone of the blade and the support. On the other half of the circle, at the side of the wind direction, there are both forces of reverse senses.

The appearing pulsating load changes, including polarity changes, have a significantly adverse effect on turbine wear and equipment efficiency. Known solutions consist in inserting additional elements into the construction of the rotor in order to stiffen the wings. For example, these may be the line tie rods - as in the rotor described in British Patent GB 2175350, or additional supports - as disclosed in the German Patent DE 3626917. The introduction of the strengthening elements results in the increase in the aerodynamic drag and the decrease of the turbine efficiency, especially if they include the acutely angled forms, which facilitate the volumetric turbulence. The adverse effect of the centrifugal force leads to partial reduction in the application of the changeable airfoil on the rotor length, with the length of the chord and the thickness of the airfoil decreasing towards both wing ends. Such solution, among others, was applied in the rotor disclosed in the patent description EP 0046370. In the brief description of the working conditions and technical problems appearing in these kinds of rotors, it is necessary to indicate the diversity of the aerodynamic force on the upper and lower wing and the construction susceptibility to the self-excited aeroelastic vibrations, that is, the flutter of the wings at high speeds of the surrounding air. The characteristics of the area may often determine the substantial decrease of the wind speed at the lower wing level.

The aim of this invention is to draw up a simple construction of the rotor, which is characterised by the high stiffness and durability, low aerodynamic drag and high efficiency of the wind pressure force transformation on the driving force of the rotor shaft.

In this invention, similarly to the above disclosed solutions, the rotor involves at least two horizontal supports connected with the hub. Rotor blades (each consisting of two wings joined together) with a symmetric or concave-convex airfoil, with chord lengths and airfoil thickness decreasing towards both wing ends are fixed tightly to the ends of the supports. The essence of the invention is that the upper and lower wing of the rotor blade deflect from the central zone radially outside at the angle relative to the rotating axis. At the same time, the chord lengths of the airfoil at both wings ends and the chord length in the central zone are approximately inversely proportional to the radiuses of their location relative to the rotating axis.

The use of the rotor with deflected wings which, at the same time, have decreasing chord and thickness of wings airfoil towards their tips, provides a stable intensity of wind power consumption along the length of the wings. Changing chord and thickness to move the center of the mass of the blades closer to the center of the wing, lowers the bending moment from the centrifugal force at the blades and their deformation. The frequency of free vibrations of blades with deflected wings and decreasing chord and thickness of airfoil is higher than that of straight blades. This facilitating result is particularly visible during gust winds. The deflected wings introduce aerodynamical twist – angle of the incoming air flow near the central zone of wing is bigger then at the wings ends. The diversity of angle attack, in practice, eliminates the danger of flutter.

The aim of the further embodiments of the invention is to eliminate the influence of different wind speeds which appear at the upper and lower levels of the rotor.

For this purpose, it is advised that the angle of the lower wing deflection in the rotor should be larger than the angle of the upper wing deflection. The advised angle difference is in the range of 1°to 5°.

The solution in which the lower wing is longer than the upper one is also beneficial. The length difference in the range of 2 to 15% is recommended.

In accordance with the invention, in the rotor it would be advisable to use supports with the symmetrical airfoil and horizontally placed chords, as well as such connection with the hub that the longitudinal axes go through the geometrical center of airfoils, and intersecting the rotating axis.

Referring to the fact that the rotor works with the highest possible efficiency if used is the optimal angle of attack of wings for a narrow range of the wind speeds, it is also useful to connect the driving blades to the supports using known set points of attack angles, which enables regulation in the range of -2° to +3°.

In order to completely understand the invention, the example of the schematic convention of the rotor is shown on the drawing. Particular figures on the drawing show: fig.1 – perspective view of the rotor with deflected wings, fig.2 – the view from the side, fig.3 – the view of the wing from the direction marked with the letter X on the fig.2, fig.4 – the view on the other rotor with wings of different length and varied deflection angles of upper and lower wings, whereas fig.5 shows the view from above on the rotor in its section according to the line Y-Y marked on the fig.4.

The rotor is fixed onto the hub 1 of the driving shaft bearing vertically in the tower of the fourth wind turbine. Two horizontal supports, with the symmetrical airfoil are fixed to hub 1.

The airfoil chords of supports are horizontal and the longitudinal axis, which goes through the geometrical center of airfoils, cuts the rotating axis of the rotor. The rotor blade 3 is fixed at the end of each support 2, the blade is connected with the support 2 by the centre zone 3c of its own length. The upper wing 3a and the lower wing 3b of the rotor blade 3 have the same length, both wings are deflected radially outside and the angle relative to the rotating axis is $\beta 1 = \beta 2$. The cross sections of the upper wing 3a and the lower wing 3b have the symmetrical or concave-convex airfoil with the chord lenghts from b1 to b2 decreasing towards both wing ends and airfoil thickness from c1 to c2. The chord lengths b2 of the airfoil at both wings ends 3a, 3b and the chord length b1 in the centre zone 3c are inversely proportional to the radius R1,R2 of their location, relative to the rotating axis, as expressed in the relation: b1/b2 = R2/R1. When the land form features apply to such dimensional and shape relations, the wind power consumption is stable along the entire length of the wing and, at the same time, the angle of the air attack α1,α2 of speed resultant T1, T2 of the airflow along the wing decreases. It is shown on the fig.3, where particular elementary surfaces of the wings, symbolically marked "1 cm" should generate the identical aerodynamic force, according to the formula:

$$Y = C_y \times S \times \rho \times V^2/2,$$

where

C_y – indicates coefficient that is dependent on the shape of the airfoil and an angle of the incoming airflow,

S – area of the elementary surface of the wing ,

ρ – air density,

V – the speed of the incoming airflow

Nearby the central zone 3c the value of the product C_y x S is higher than at the end of the wing, where V^2 is a predominant value. In case of gust winds, the angle of the air attack α may exceed the critical value. By changing the value of the deflection of the wing and sizes of chord of central zone and end of the wing, it's possible to reach even distribution of the aerodynamically force along the wing.

In the rotor, in accordance with the invention, the angle of the the incoming airflow decreases continuously from α1 in the centre zone 3c to α2 at the ends of the wings 3a, 3b – creation of aerodynamical twist. The wing with the aerodynamical twist has its critical angle of attack starting at the central zone and gradually can reach the end of the wing. That's why the process of creation of the turbulence zone behind the wings also has gradual character that does not provoke pulsation in turbine or vibrations of the tower 4 and supports 2, which appear in turbines with straight blade rotors.

The outside deflection of the wings 3a, 3b allows for shortening the support 2 appropriately – which has the decreasing effect on the turbine aerodynamic resistance.

The rotor adapted to the balanced wind power consumption by the upper wing 3a and lower wing 3b is shown on the fig. 4, for the land conditions in which the wind speed is significantly diversified depending on the height above the ground level. The difference between aerodynamic powers appearing on the lower wing 3b and upper wing 3a creates the adverse torque moment of the supports.

The balance of the aerodynamic forces can be ensured with the use of the larger (by for example 3°) deflection angle β_2 of the lower wing 3b than the deflection angle β_1 of the upper wing 3a, maintaining equal lengths of the wings $l_1 = l_2$. The increase of the deflection angle value increases the circumferential speed of the lower wing and the aerodynamic forces generated by the upper and lower wings become equal. The load balance of the upper 3a and lower 3b wing can be also achieved at equal deflection angles $\beta_1 = \beta_2$ but longer lower wing 3b length l_2 – for example about 10 % longer than the length l_1 of the upper wing 3a.

Testing of the rotor prototype, as specified in the invention, revealed that maximum efficiency of the power conversion for the different wind speeds W is achieved at different angles of attack γ, between the centre zone chord 3c and tangent line to trajectory of the movement of this section, fig 5. For example, for the wind speed W=6 m/s, angle = -2°, for W= 9,5 m/s γ = 0° and for the W= 11 m/s γ = +2° The rotor in the subject of the invention is equipped with one of the known solutions built-in to the support 2, which allows for changing the attack angle γ, during the operation of the turbine.

CLAIMS

1. A wind turbine rotor with a vertical rotation axis, having connected with a hub, at least two horizontal supports on ends of which are rotor blades fixed in their central zone to the support ends, each rotor blade consisting of two wings joined together, transverse sections of which wings have a symmetrical or concavo-convex airfoil, wherein the length of the chord and the thickness of the airfoil are diminishing towards wings ends, characterised in that an upper wing (3a) and a lower wing (3b) of the rotor blade (3) radially deflect from the central zone (3c) outwards, forming a deflecting angle (β_1,β_2) towards the rotation axis of the rotor, where the length of chord (b2) of the airfoil at the both wing ends (3a, 3b) and the length of the chord (b1) in the central zone (3c) are approximately inversely proportional to the radii (R1 , R2) of their location in relation to the rotation axis of the rotor.

2. The rotor according to the claim 1, wherein the deflecting angle (β_2) of the lower wing (3b) is greater than the deflecting angle (β_1) of the upper wing (3a).

3. The rotor according to claim 2, wherein the deflecting angle (β_2) of the lower wing (3b) is greater by 1° to 5° than the deflecting angle (β_1) of the upper wing (3a).

4. The rotor according to the claim 1 or 2, wherein the length (l_1) of the lower wing (3b) is greater than the length (l_2) of the upper wing (3a).

5. The rotor according to the claim 4, wherein the length (l_1) of the lower wing (3b) is greater by 2 to 15% than the length (l_2) of the upper wing (3a).

6. The rotor according to the claim 1, wherein the supports (2) have a symmetrical airfoil with a horizontally positioned chord and the longitudinal axis of the supports goes through the geometrical center of airfoils and intersects the rotation axis of the rotor.

7. The rotor according to the claim 1 or 6, wherein the rotor blades (3) are connected with the supports (2) by means of using predetermined setpoints of attack angle (y) setting the angle of stall (y) in the range of -2° to +3°.

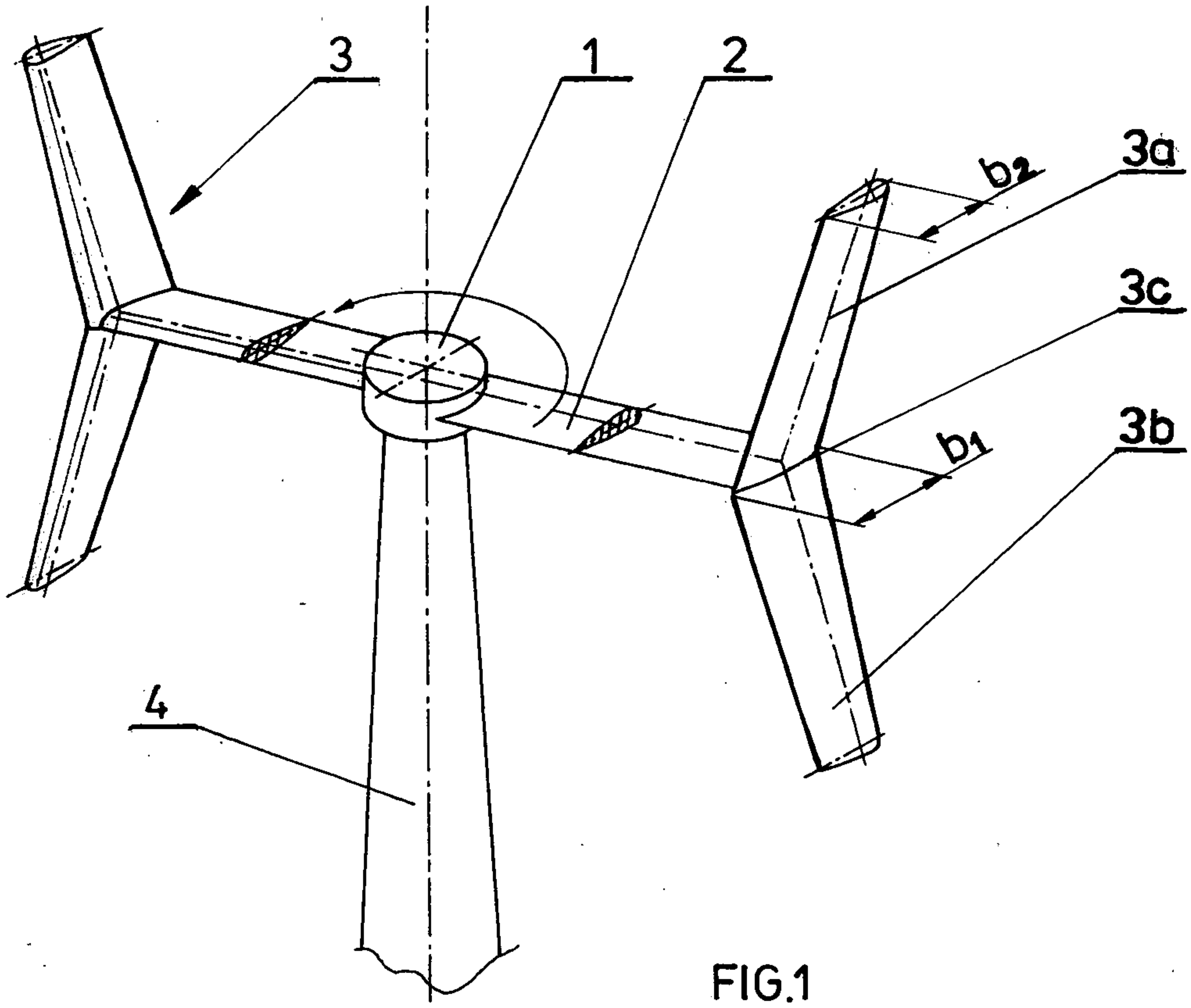


FIG.1

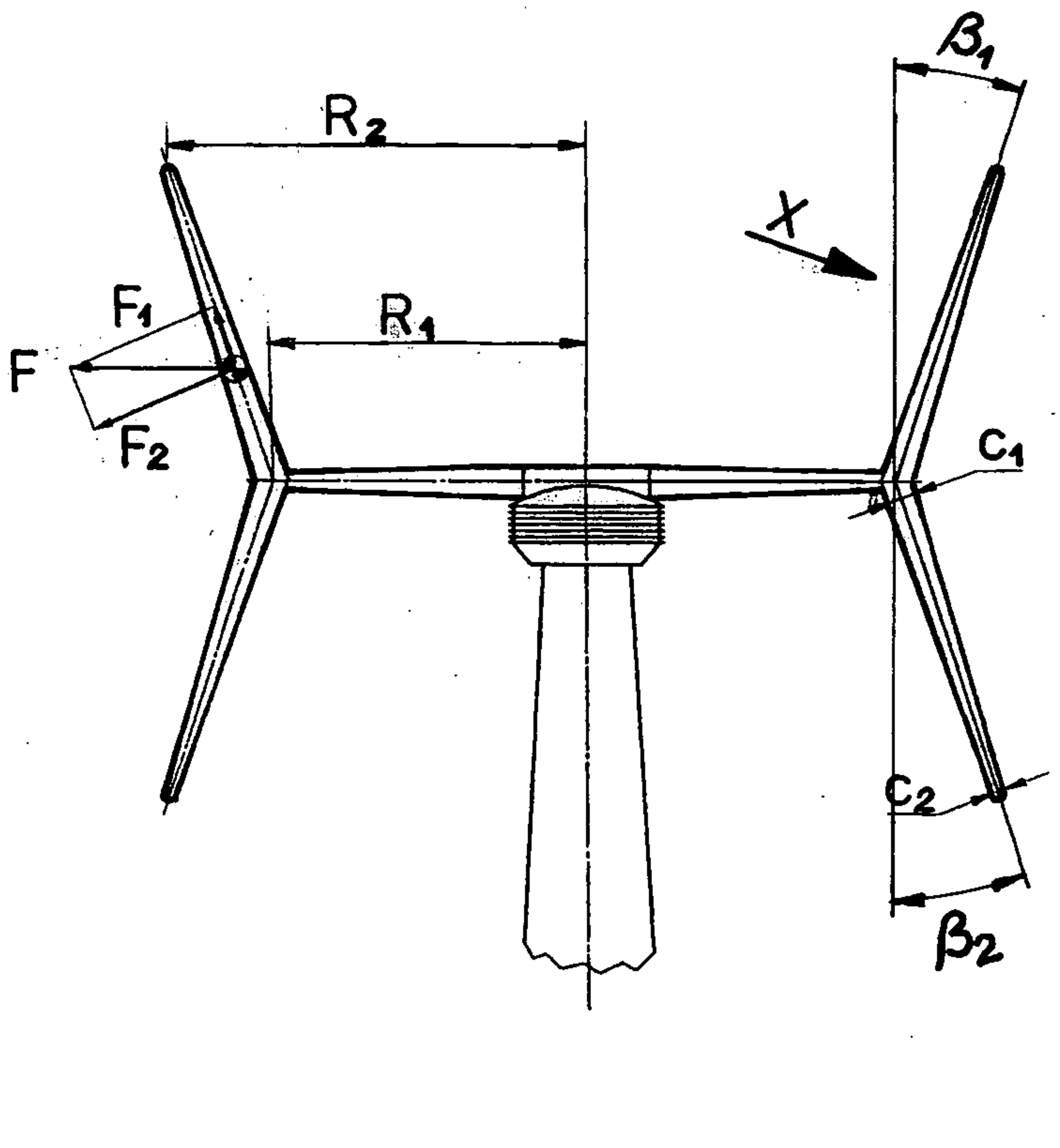


FIG.2

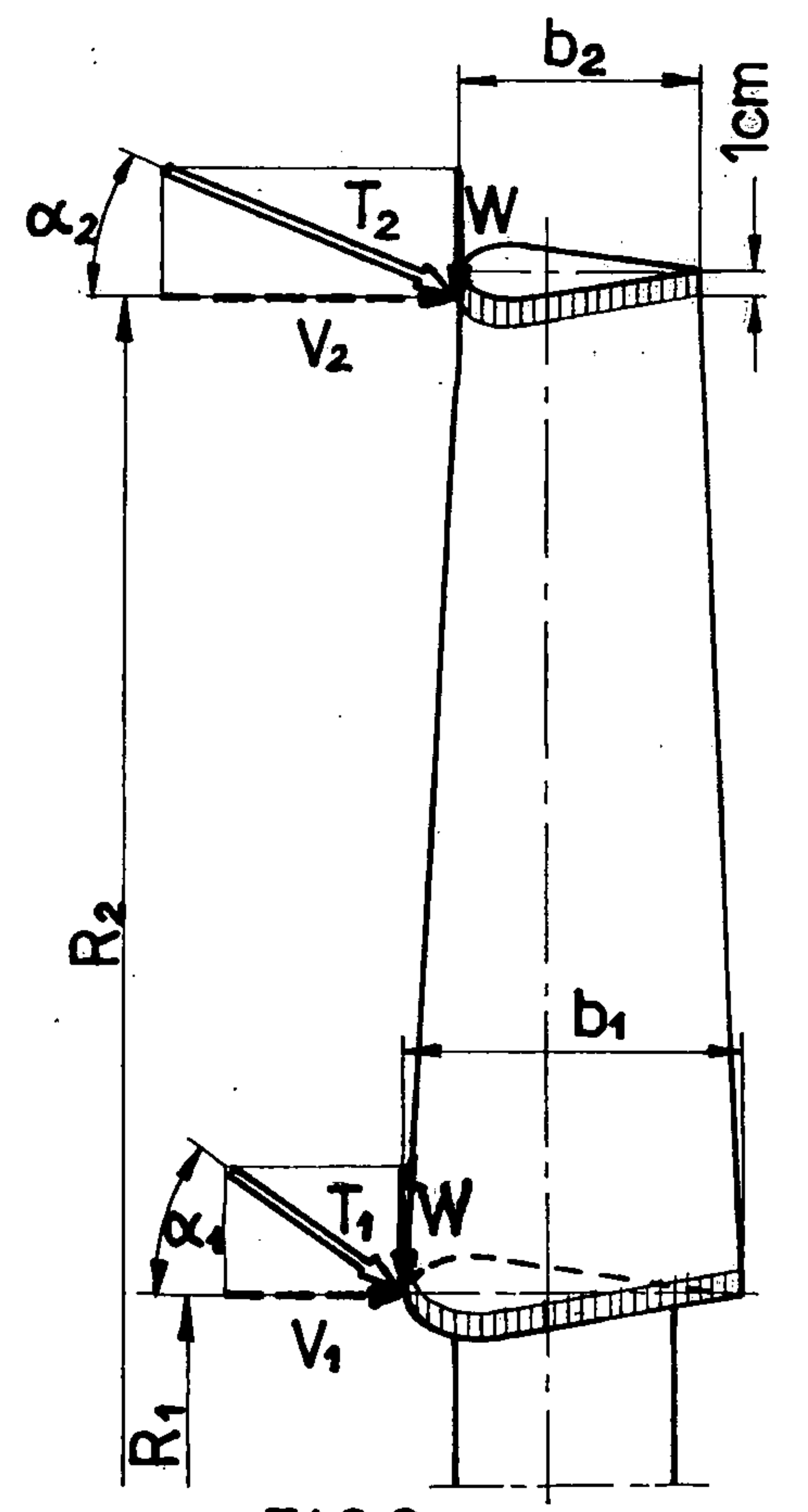


FIG.3

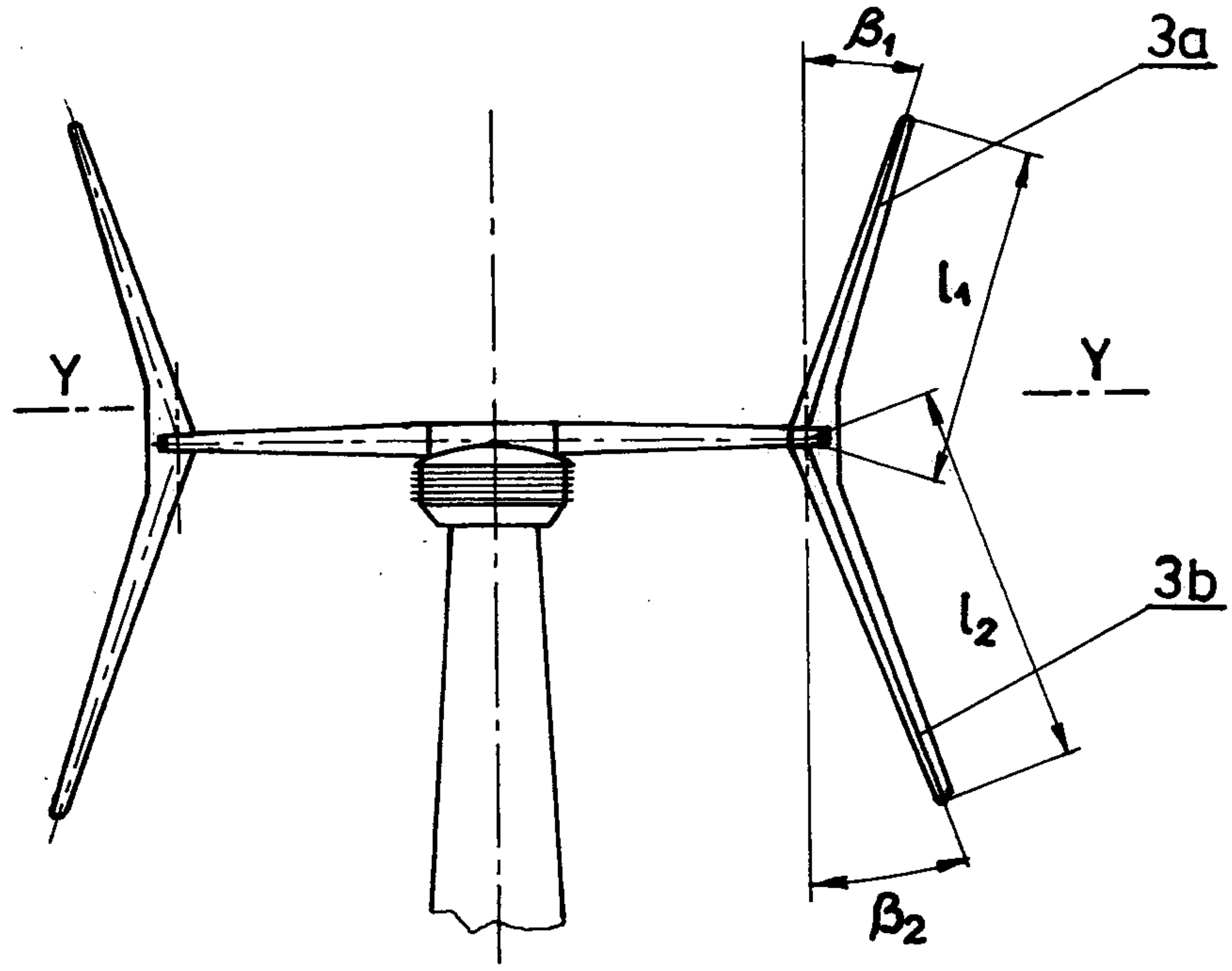


FIG.4

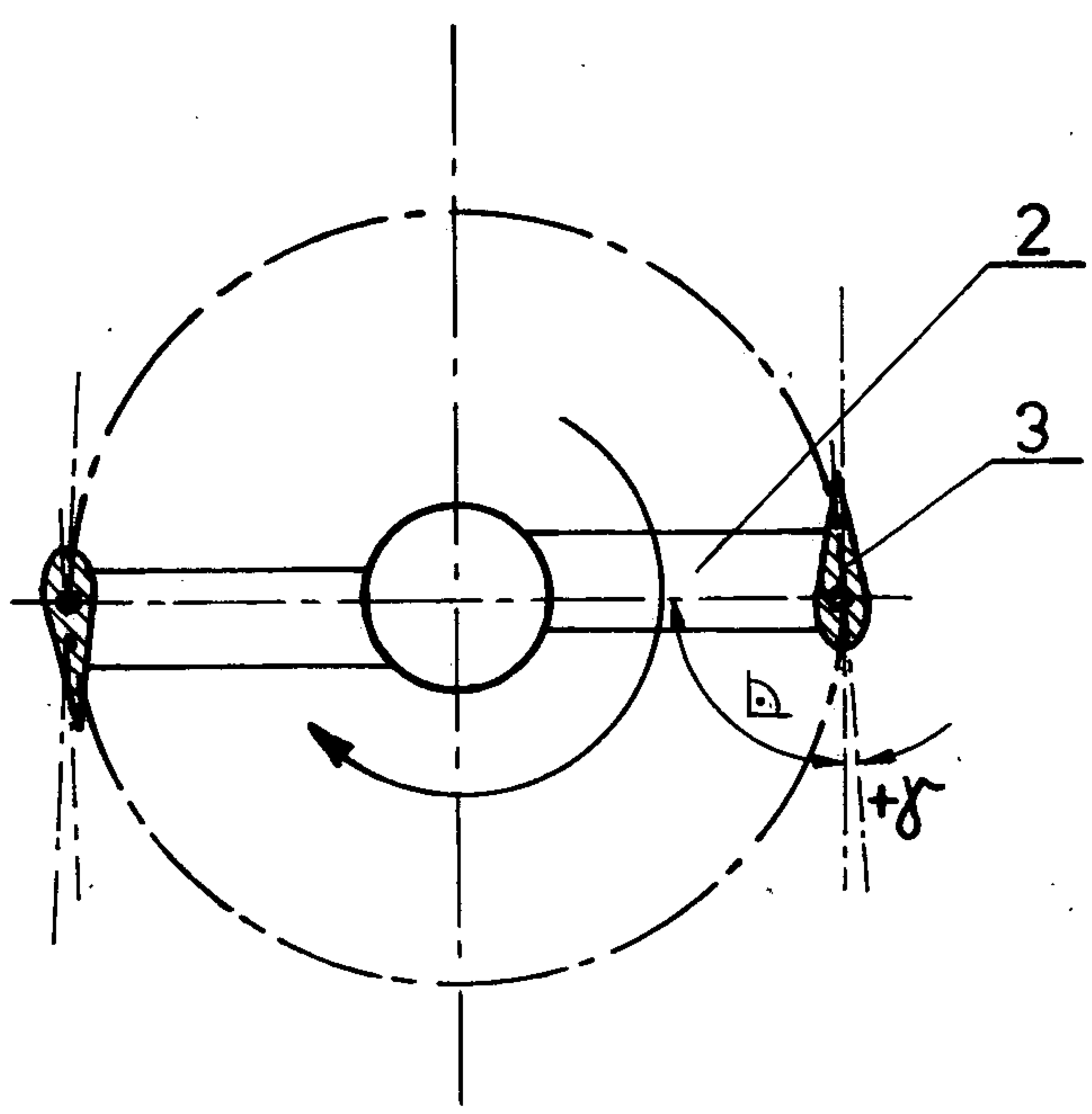
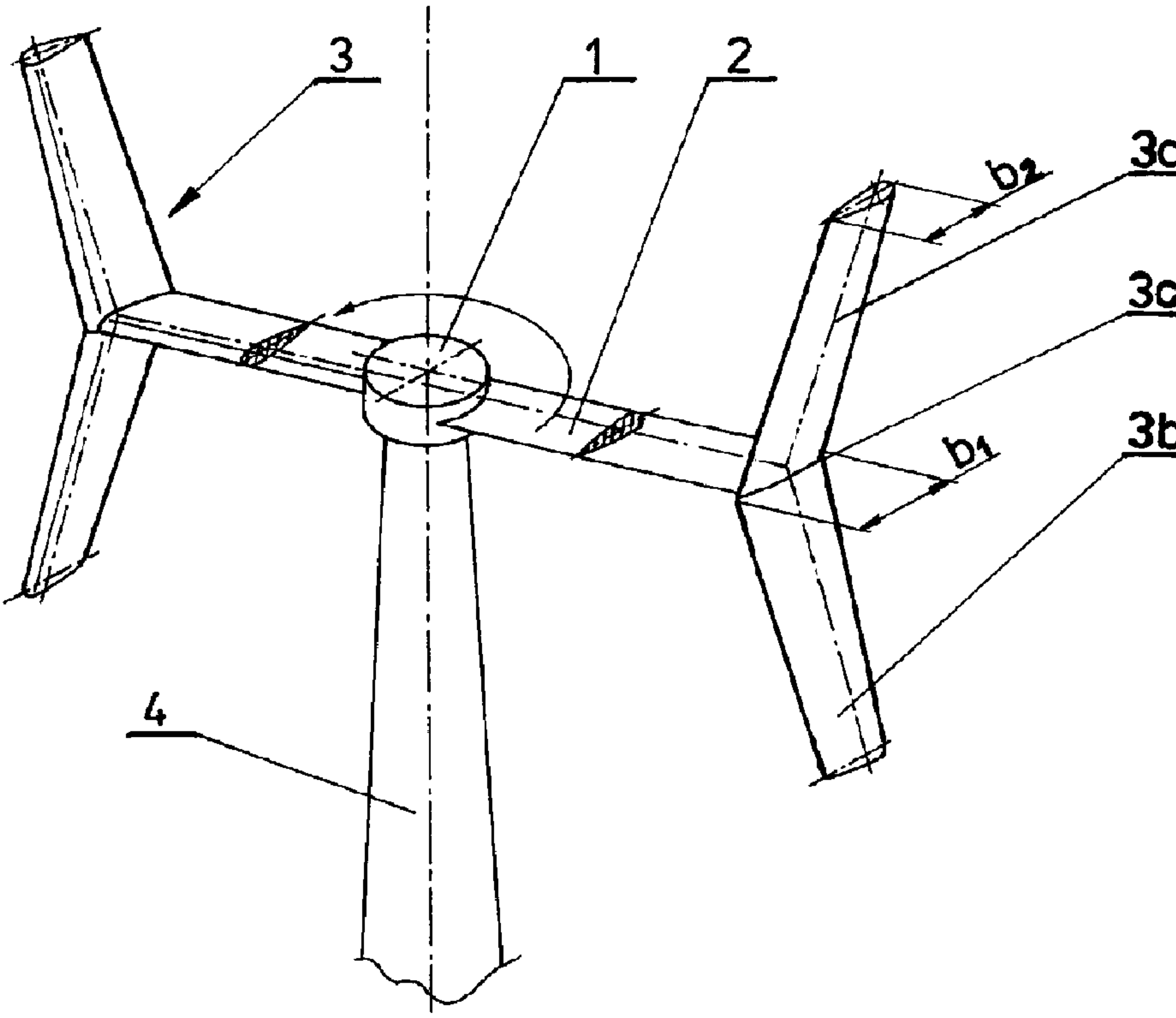


FIG.5



3
1
2
3a
b2
3c
b1
3b
4