



(22) Date de dépôt/Filing Date: 2005/02/10

(41) Mise à la disp. pub./Open to Public Insp.: 2005/08/25

(45) Date de délivrance/Issue Date: 2014/02/04

(62) Demande originale/Original Application: 2 554 666

(30) Priorité/Priority: 2004/02/13 (DE10 2004 007 487.9)

(51) Cl.Int./Int.Cl. *F03D 1/06* (2006.01)

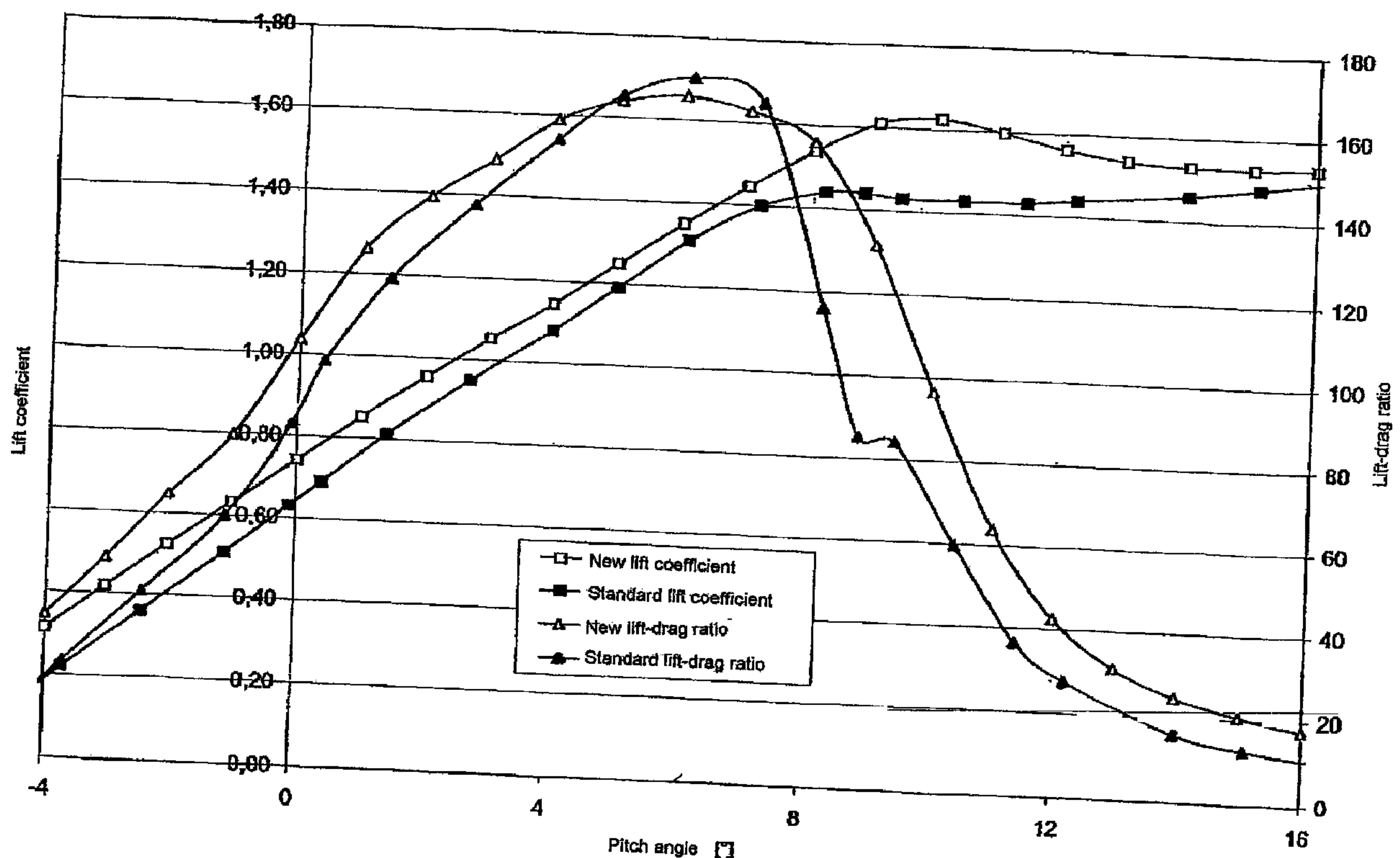
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(54) Titre : PALE D'UNE INSTALLATION D'ENERGIE EOLIENNE

(54) Title: ROTOR BLADE FOR A WIND TURBINE



(57) Abrégé/Abstract:

The invention relates to a rotor blade for a wind turbine and to a wind turbine comprising a rotor with rotor blades of this type. The aim of the invention is to prevent the described disadvantages and to guarantee an improved overall performance. To achieve this, the invention provides a rotor blade with a drag ratio, in particular in the central or main board region of said rotor, whose value exceeds 80 % and preferably 90 % of the maximum value of said ratio in the range of $\sim 2^\circ$ of the optimum pitch of said rotor.



Abstract

- 5 The invention relates to a rotor blade for a wind turbine and to a wind turbine comprising a rotor with rotor blades of this type. The aim of the invention is to prevent the described disadvantages and to guarantee an improved overall performance. To achieve this, the invention provides a rotor blade with a drag ratio, in particular in the central or main board
- 10 region of said rotor, whose value exceeds 80% and preferably 90% of the maximum value of said ratio in the range of $\pm 2^\circ$ of the optimum pitch of said rotor.

Rotor blade for a wind turbine

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The invention concerns a rotor blade of a wind power installation and a wind power installation comprising a rotor having such rotor blades.

The performance of a wind power installation and in particular the efficiency thereof is determined to a not inconsiderable degree by the rotor
10 blades or the rotor blade design. The rotor blades are described by a large number of parameters, in which respect attention is directed at this juncture generally as state of the art to the book by Erich Hau, Windkraftanlagen, 3rd edition, 2002, in particular pages 90 ff thereof.

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As mentioned the operational efficiency and also the regulating performance of wind power installations are governed to a not inconsiderable extent by the aerodynamic properties of the rotor blade
20 profiles used. An important parameter of a rotor blade profile is characterised by the ratio of the lift coefficient c_a and drag coefficient c_w :

$$\frac{c_a}{c_w} = E$$

wherein E is referred to as the lift-drag ratio.

In addition an important parameter of a rotor blade is the high-speed
25 factor λ wherein the high-speed factor is defined by the quotient of the peripheral speed (u) of the tip of the rotor blade and the wind speed v.

Figure 1 shows the known afflux flow conditions and the air forces at the profile cross-section of a blade element.

If the profiles of known rotor blades are investigated, a particular
30 relationship between the lift-drag ratio and the pitch angle is established. More specifically it is found that the lift-drag ratio is greatly dependent on the respective pitch angle and typically a high lift-drag ratio is achieved

only in a quite limited pitch angle range. Thus for example a high lift-drag ratio can be achieved if the pitch angle (of a rotor blade) is in the region of 6° and at the same time however the lift-drag ratio falls severely as soon as the pitch angle slightly rises above or falls below the region of 6° .

5 If the value leaves the region of the optimum lift-drag ratio, that is to say the pitch angle is markedly different from the optimum pitch angle, for example 6° , it can be easily seen that the overall efficiency of the installation is less with the consequence that the wind power installation will have a tendency either to set the pitch angle to the optimum values
10 again, for example by pitch control, and/or to set the entire rotor into the wind in the optimum relationship by orientation of the pod.

 The size of the rotors of wind power installations have steadily increased in recent years and swept rotor areas of 10,000 square metres are in the meantime no longer theory but have become practice, for
15 example in the case of a wind power installation of type E112 from Enercon. That involves a wind power installation whose rotor diameter is about 112 m.

 It is now in practice impossible to achieve the optimum of the lift-drag ratio over all regions of the rotor blade because, with the very large
20 swept area, it is no longer possible to assume that the wind is always flowing against the rotor blade from the same direction and always at the same speed.

 The consequence of this is that in some regions the rotor blade or blades admittedly operate in a relatively optimum manner but in some
25 other regions the rotor blades rather operate in sub-optimum manner by virtue of the different nature of the afflux flow profile in the swept rotor area. That results directly from the very close dependency of the lift-drag ratio on the afflux angle and the consequence of this is that the loads on the rotor blade can fluctuate in an extreme fashion because the lift (c_a) of
30 the rotor blade is also approximately proportional to the lift-drag ratio.

 It will be appreciated that, as a way of improving the above-indicated problems and to avoid the disadvantages thereof, it is possible to always find an optimum setting by suitable pitch control of the rotor blades

or by virtue of yaw of the entire rotor. It will be readily apparent to the man skilled in the art however that, with that concept, the rotor blades must in practice be constantly set into the wind (that is to say must be pitched) and/or the azimuth drives must also constantly freshly orient the rotor without that substantially improving the situation.

The object of the invention is to avoid the above-indicated disadvantages and to provide for a better overall performance.

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One of the essential properties of the rotor blade design according to the invention is that the lift-drag ratio remains virtually high over a quite large pitch angle range, but in that respect the highest value in respect of the lift-drag ratio now remains behind the optimum of the previous lift-drag ratio from the state of the art. Expressed in other terms, the lift-drag ratio of the rotor blade according to the invention, with optimum setting of the pitch angle is – at a maximum – lower than in the state of the art, but at the same time a departure from the optimum setting does not immediately lead to a substantial reduction in the lift-drag ratio and the lift coefficient and thus a loss of lift, but deviations which are in the range of for example ± 0.5 to 3° from the optimum setting angle do not lead to the substantial reduction in the lift-drag ratio and thus the reduction in lift with the consequence that the overall blade efficiency is improved. That also achieves a markedly better distribution of load and a markedly low fluctuation in load ($\Delta L/dt$). As can be seen from Figure 2 the 'saddle' of the lift-drag ratio curve of the rotor blade according to the invention in the range between 4 and 8° pitch angle is markedly wider than in the case of a known rotor blade.

The claimed design configuration of the rotor blade is to be found in particular in the central third of the rotor blade, that is to say in the so-called region of the main board of the rotor blade. That is the region which is between the rotor blade attachment region or rotor blade root region on

the one hand and the tip region, that is to say the outer end region, of the rotor blade.

Figure 2 shows the variation in the lift coefficient or the lift-drag ratio on the one hand relative to the pitch angle. In particular the curve diagrams relative to the pitch angle show that, in the case of a standard rotor blade, the lift-drag ratio reaches its absolute maximum which is at about 170 in the region of the pitch angle of about 6° . The lift-drag ratio already falls severely upon a departure from the pitch angle of 6° by 1° , that is to say either to 7° or 5° , and in particular towards higher pitch angles the lift-drag ratio is already halved when the pitch angle assumes a value of about 9° . Towards lower pitch angles there is also a very sharp drop which however is not quite as steep as when the pitch angle differs towards higher pitch angles.

The variation in the lift-drag ratio in the case of a rotor blade according to the invention can also be seen in the diagram. The maximum is once again pronounced in the region of the pitch angle of about 6° and that maximum is below the maximum of the lift-drag ratio in the case of a standard rotor blade. It will be noted however that the 'saddle' of the optimum is now markedly wider as can be seen from the intersecting curves and when for example the pitch angle is in the range of 4 to 8° , that is to say $\pm 2^\circ$ from the optimum pitch angle of 6° , the lift-drag ratio is reduced only by about 10% from its optimum value. In the region of about 4.5° to -4° on the one hand and in the region of about 7° to 16° the lift-drag ratio is always above the lift-drag ratio curve for a known rotor blade.

As can also be seen the configuration of the rotor blade according to the invention overall improves the lift coefficient of the entire rotor blade, which is accompanied by an increase in efficiency of about 15% of the rotor blade.

In particular the load fluctuations are also now no longer as great as hitherto and, with any very small change in the pitch angle, there is no need to effect at the same time corresponding measures to re-set the pitch angle to the desired optimum value, in the present example 6° .

Figure 3 shows various views of a rotor blade tip, that is to say a rotor blade end portion. Figure 3a shows a perspective view of a rotor blade tip, Figure 3b shows a side view and Figure 3c shows a plan view.

That rotor blade tip is also usually referred to as an edge arc. It can be seen from Figure 3a that the edge arc is illustrated with three profile sections and the thread axis.

The three different illustrations make it possible to show the rotation of the profile of the edge arc about the thread axis. In that respect the illustrated rotation is greater in terms of magnitude than the number of degrees specified in the description in order for reasons of illustration to make the representation in the illustration in the drawing perceptible at all to some degree.

It should be particularly emphasised once again at this juncture that the configuration according to the invention of the rotor blade concerns in particular the central portion, that is to say the so-called main board, that is to say the region which is between the rotor blade root region and the tip region. The main board can also be described generally as the 'central third' of a rotor blade, in which respect the specific dimensions over the main board can differ therefrom and the main board for example can also occupy approximately up to 60% of the rotor blade length.

Additionally or independently of the aforementioned configuration of the rotor blade, a further improvement can also be achieved – see Figures 3a to 3c – if the rotor blade tip, that is to say the tip end portion, is rotated in a given region around the thread axis, for example through about 4 to 8°, preferably about 5°, around the thread axis (twist). The twist is then in a so-called neutral afflux angle, that is to say the tip itself affords no contribution to lift. A typical configuration of a tip or a corresponding tip end section is known from the above-mentioned book by Erich Hau, page 126 (Figure 535).

In accordance with the general school of thought the dimensioning loads of a rotor blade are calculated as the product of the square of the wind speed, the rotor blade area and the lift coefficient. Expressed as a formula the

dimensioning load = $v_2 \times A \times c_A$,

wherein the rotor area A is used to denote the area which the rotor covers (sweeps).

This in consideration of the textbooks is quite rough and does not
5 always correspond to reality. The greatest load of a rotor blade does not act
thereon in normal operation but when a so-called once-in-50-years gust
'catches' the rotor blade from the side. In that case the gust acts on
precisely the entire rotor blade surface. In that respect it can be seen
straightaway that the lift coefficient c_A plays no part, rather the resistance
10 coefficient c_W would be considered here. The resistance coefficient however
is always constant for that more or less flat rotor blade surface for, if the
wind impinges on a blade, then it impinges precisely on a board. That
situation, namely full lateral afflux flow, is the worst-case situation in which
the greatest load for which the rotor blade must be dimensioned, precisely
15 a dimensioning load, occurs.

It will be apparent from the foregoing that, with a constant
resistance coefficient, it is simply and solely the area of the rotor blade that
is crucial. That is also the reason for the slenderest possible configuration
of the rotor blades.

20 It is however known that the power output of a wind power
installation crucially depends on the length of the rotor blades. Therefore
long slender blades are hitherto to be preferred to wide short blades. It will
be noted however that the point is not to be overlooked in that respect that
this consideration does not apply to the blade inner region (main board) as
25 here the situation is fundamentally different.

Finally the relative speed of the rotor blade relative to the air flowing
therearound in the region of the blade root is the lowest and rises
continuously towards the blade tip. Therefore the rotor blade shape
described herein with the narrow outer region and the optimised lift-drag
30 ratio is a particularly advantageous solution.

WHAT IS CLAIMED IS:

1. A wind power installation rotor blade having a tip or a tip end plate which rises out of the plane of the rotor blade in the manner of a winglet, wherein said tip or end plate is rotated about a thread axis in a central plane by 4° to 6° .

2. A wind power installation rotor blade as defined in claim 1, the rotor blade comprising:

a root region;

a tip region;

a central region comprising at least one third of the rotor blade and extending between the root and tip regions;

wherein,

at least in the central region, the rotor blade has an aerodynamic profile

characterized by a lift coefficient, a drag coefficient, and a maximum ratio of the lift and drag coefficients at an optimum pitch angle; and

the profile is adapted to optimize efficient operation of the wind power

installation, such that within a $\pm 2^{\circ}$ range of the optimum pitch angle the ratio of the lift and drag coefficients is constrained to a value which

exceeds 80% of the maximum ratio and is less than the maximum ratio.

3. A wind power installation rotor blade as defined in claim 2, wherein the profile is adapted to optimize efficient operation of the wind power installation, such that within a $\pm 2^{\circ}$ range of the optimum pitch angle the ratio of the lift and drag coefficients is constrained to a value which exceeds 90% of the maximum ratio and is less than the maximum ratio.

4. A wind power installation having at least one rotor blade in accordance with any one of claims 1, 2 or 3.

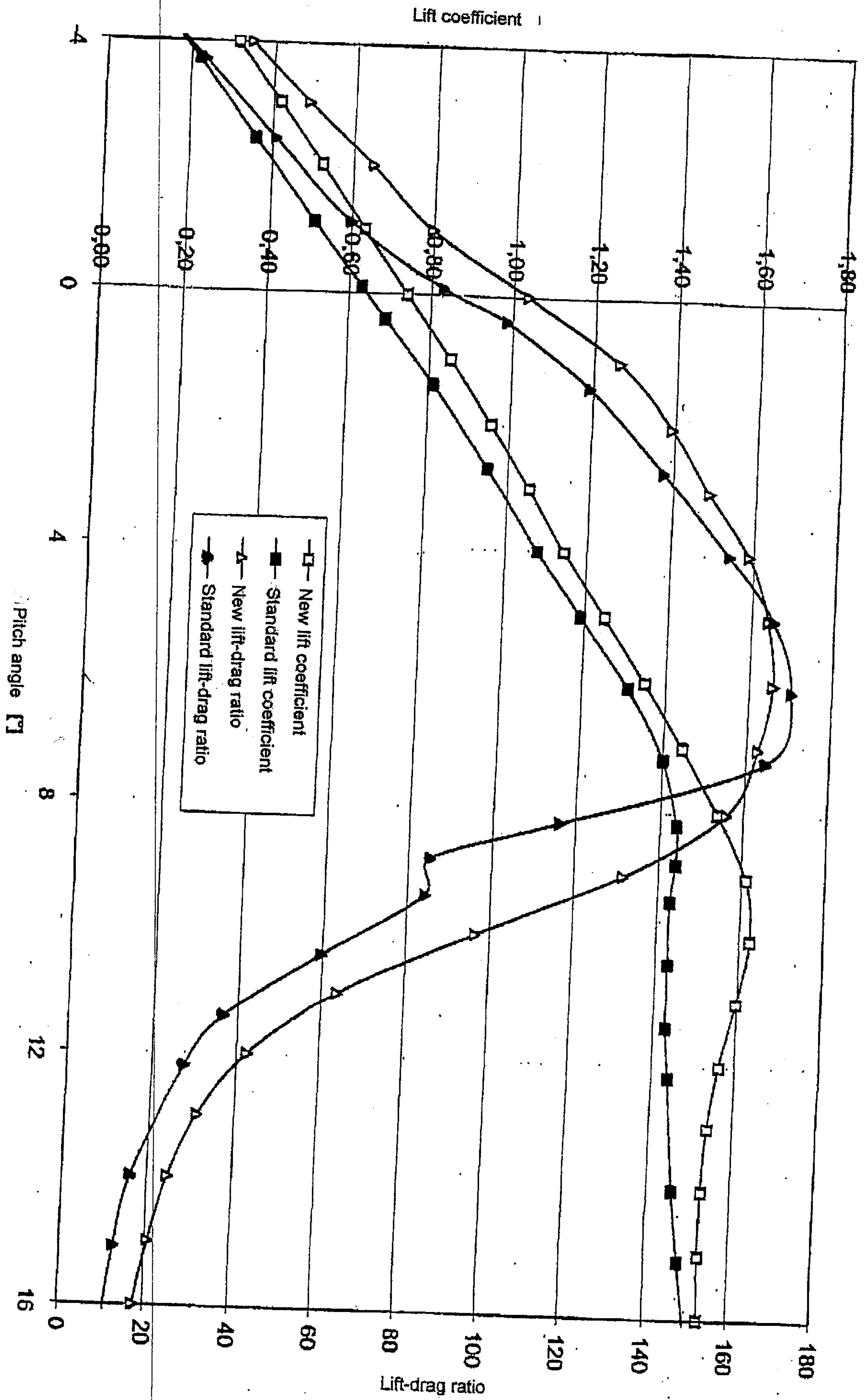


Fig. 2

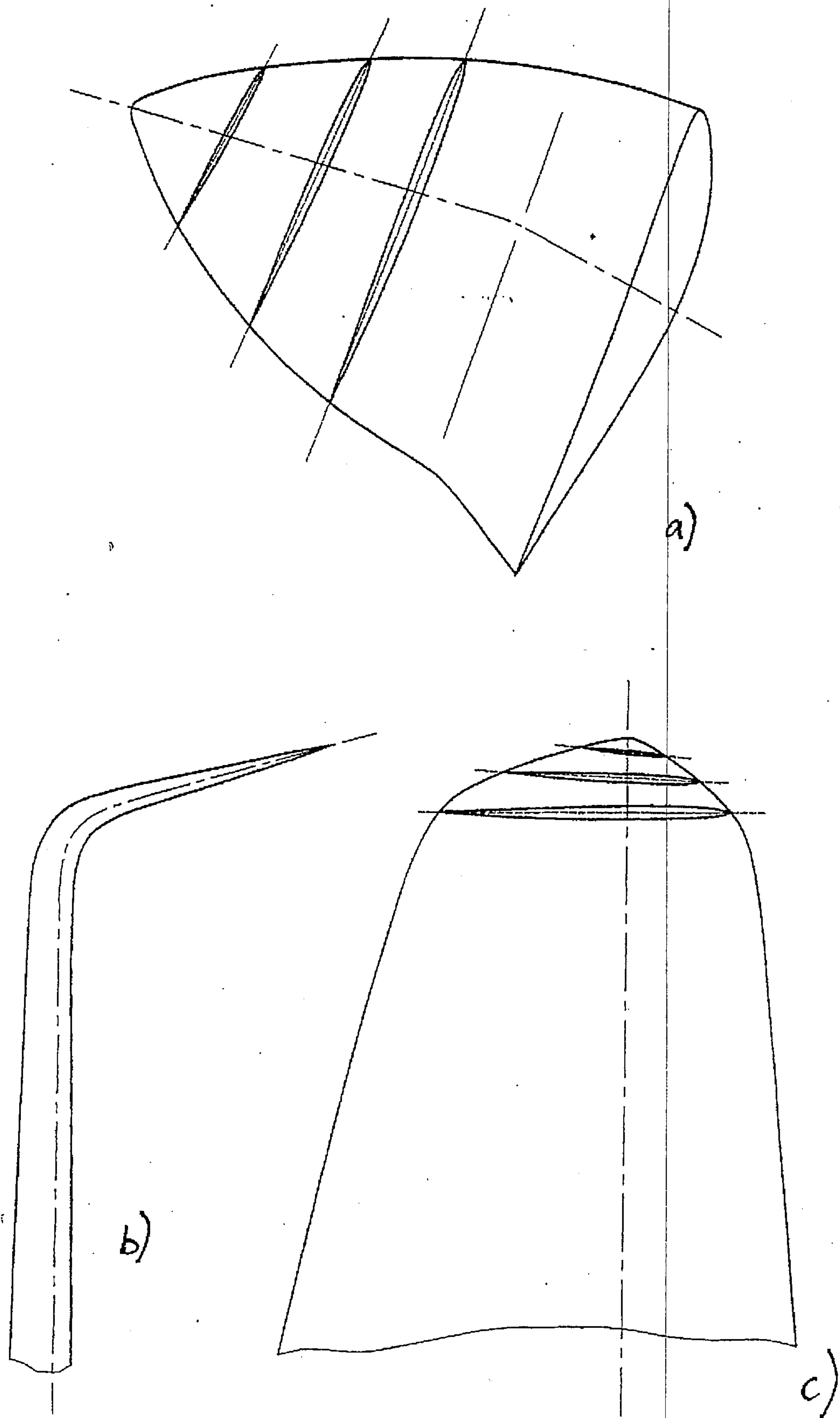


Fig. 3

