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DESCRIPTION

BACKGROUND

Statement of the Technical Field

[0001] The present disclosure relates to blades. More specifically, the present disclosure relates to blades having incorporated flow deflectors.

Description of the Related Art

[0002] Wind turbines produce power proportional to the swept area of their blades, and the amount of air flow passing over the blades at any given time. Various design choices such as rotor diameter, blade length and load limitations are considered during design and fabrication of a wind turbine. Longer blades provide for more energy production in low winds. However, longer blades require more materials, higher manufacture and transportation costs, larger and more robust rotor design to support the added weight of the longer blades, and failsafe systems for preventing potential damage to the turbines in high wind situations as the longer blades may produce damaging levels of torque at high wind speeds.

[0003] Conversely, using shorter blades has its own set of drawbacks. For example, in low winds shorter blades may not have enough surface area to produce enough torque to move the rotor, thereby producing no power.

[0004] Regardless of size, all wind turbine blades are limited in overall efficiency due to various resulting properties of the air flow. Due to the rotational movement of the blades during operation, at least a portion of the air flow impacting the blade is converted to a radial component moving about the length of the blade from the root toward the tip of the blade. Fig. 1 illustrates a standard wind turbine 10 with a mast 12 supporting a hub 14 from which a plurality of blades 16 are supported. The mass of air affected by the turbine forms a stream tube as the wind must slow down due to energy extracted by the turbine. Wind W directed at the turbines will have an initial area as indicated by the circle 18. As the wind W reaches the blades 16, the air flow has two components, namely an axial flow W_A and a radial flow W_R, with the area of the wind flow expanding radially as indicated by circle 20 due to the conservation of mass flow rate along the stream tube. The flow continues to expand radially downstream, as indicated by the increased area at circle 22, since the pressure in the wake must return to the atmospheric pressure after a pressure drop experienced by passing though the rotor disc. Based on the conservation of momentum, this radial flow W_R reduces the efficiency of the turbine since it creates a radial force from the available total force from the wind. This radial

force is not contributing to any torque or power produced by the rotor.

[0005] The present disclosure addresses these and other similar problems resulting from conventional blade design. It allows the blade to convert part of that radial force into a tangential force by redirecting the radial flow W_R, thereby increasing the torque and power extracted by the turbine US 2013/0224037 A1 discloses protrusions on the pressure or suction surface of the air foil forming venturi channels that affect the flow along the air foil surfaces.

SUMMARY

[0006] In at least one embodiment, the present disclosure describes an airfoil blade assembly according to appended claim 1.

[0007] In at least one embodiment, the present disclosure describes a turbine assembly according to appended claim 15. The flow deflectors are not limited to wind turbines but may be positioned on blades used in various applications, for example, helicopters, hydro turbines, airplane wings, engines, propellers, and industrial turbines.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments will be described with reference to the following drawing figures, in which like numerals represent like items through the figures, and in which:

Fig. 1 is a perspective view of an example prior art wind turbine and the corresponding typical air flow thereabout.

Fig. 2 is a perspective view of an example of a wind turbine having blades incorporating flow deflectors in accordance with an embodiment of the present disclosure.

Fig. 3 is a perspective view of an example blade incorporating flow deflectors in accordance with an embodiment of the present disclosure.

Fig. 4 is a cross-sectional view along the line 4-4 in Fig. 3.

Fig. 5 is a cross-sectional view along the line 5-5 in Fig. 3

Fig. 6 is a top plan view of a portion of the blade of Fig. 3.

Fig. 7 is a top plan view of a blade incorporating a flow deflector in accordance with an embodiment of the disclosure and illustrating the resultant forces thereon.

Fig. 8 is a top plan view of another blade incorporating a flow deflector in accordance with an embodiment of the disclosure and illustrating the resultant forces thereon.

DETAILED DESCRIPTION

[0009] As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. As used in this document, the term "comprising" means "including, but not limited to."

[0010] The present disclosure relates to deflectors positioned on either the pressure surface or suction surface of a blade. The blades will be described herein in conjunction with a wind turbine, however, the disclosure is not limited to such and the deflectors may be positioned on blades used in various applications, for example, helicopters, hydro turbines, airplane wings, engines, propellers, and industrial turbines.

[0011] Referring to Figs. 2-6, blades 30 incorporating flow deflectors 50 in accordance with an embodiment of the disclosure will be described. The blades 30 are illustrated positioned on the hub 14 of a wind turbine 10 with the hub 14 supported by a mast 12. The hub 14 and blades 30 rotate about an axis of rotation AR. Each blade 30 extends radially along a radial axis RA from a root 40 to a tip 42. Each blade 30 generally includes three sections, namely a root section 32, a transition section 36 and a lift generating section 34. The root section 32 connects the blade 30 to the hub 14. The lift generating segment 34 is furthest from the hub 14 and includes a profiled body 37 extending between a pressure surface 39 and a suction surface 38. The profiled body 37 extends between a leading edge 31 and a trailing edge 33. A chord 35 is defined from the leading edge 31 to the trailing edge 33 and is perpendicular to the radial axis RA. The chord 35 has a length L and the profile body 37 has a height H.

[0012] According to the invention, a plurality of flow deflectors 50, 50' are provided along the pressure surface 39, the suction surface 38 or both surfaces within the lift generating section 34. The flow deflectors 50, 50' are positioned spaced apart from the first leading edge 31 of the blade 30,30' and proximate to the first trailing edge of the blade 30,30'. In the illustrated embodiment, a pair of flow deflectors 50 are positioned along the suction surface 38 of each blade 30 and a single flow deflector 50' is positioned along the pressure surface 39 of each blade 30. The number and position of the deflectors 50, 50' are not limited to the illustrated embodiment and can be selected depending on the configuration of the blade 30 and the operating environment. The deflectors 50, 50' may be formed integral with blade 30 or may be formed separately and attached thereto. For example, the deflectors 50, 50' may be attached to the blade 30 utilizing aerospace double-sided tape with a thickness on the order of micrometers or utilizing small flat head rivets to minimize drag. Various other attachment mechanisms may be utilized. Additionally, the deflectors 50, 50' may be provided along the surfaces during original manufacture of the blades 30 or may be attached to existing blades 30 in a retro-fit fashion. Furthermore, the deflectors 50, 50' may be adjustably positioned such

that the position and orientation may be adjusted to correspond to current operating condition (e.g. more or less wind).

[0013] Each flow deflector 50, 50' has a profile body 52 extending from a leading edge 51 to a trailing edge 53. A chord 55 is defined from the leading edge 51 to the trailing edge 53 and is perpendicular to the radial axis RA or at angle a thereto as described hereinafter. The chord 55 has a length l and the profile body 52 has a height h and a width w. Each profile body 52 has an outer surface 54 and a contact surface 56, 56' and defines a streamline body, such as a flat plate or a thin airfoil. The deflectors 50, 50' generally extend such that they extend beyond the boundary layer flow over the blade 30.

[0014] The flow deflectors 50, 50' are sized proportional to the blade 30. According to the invention, the flow deflectors have a second chord length l which is between 1/8 to 1/2 of the first chord length L of the blade at the location of each of the plurality of flow deflectors 50,50'. Also, the flow deflectors may have a height h which is between 1/10 to 1 that of the blade height H, and more preferably between 1/8 to 1/2 of the height H. Also, the width w of the flow deflections may also be proportional to the chord length L of the blade 30, with a width w between about 1-10% of the blade chord length L. It is understood that if more than one deflector 50, 50' is positioned on the blade 30, the deflectors 50, 50' may have different configurations. For example, the suction surface deflectors 50 may be sized differently than the pressure side deflectors 50', however, it is also possible that there may be differences in configuration between multiple suction surface deflectors 50 or multiple suction pressure deflectors 50'.

[0015] Referring to Fig. 6, each of the deflectors 50, 50 may be positioned at an angle α relative to the blade 30. More specifically, the chord 55 of each deflector may be at an angle α relative to the chord 35 of the blade 30. The angle α may be between about -5° and 45 ° and more preferably between about 0° and 15°. If multiple deflectors 50, 50' are positioned along either surface 38, 39, they may be at different angles α. The deflectors 50, 50" are spaced from one another in the direction of the radial axis RA by a distance D. The distance D may vary between deflectors 50, 50' on a given surface and between surfaces. As one example, the distance D may be equal to the chord length L.

[0016] Referring to Figs. 7 and 8, an illustration of resultant increased efficiency from the flow deflectors 50, 50' will be described. Fig. 7 shows the moment, $M+M_{D1}$, and force, F_T+F_{D1}, generated by a blade 30 with a deflector 50. The additional force contribution by the deflector to the turbine blade is F_{D1}. This force generates an additional moment M_{D1} which contributes to the total power generated by the turbine. Fig. 8 shows an in-plane curved wind turbine blade 30' with a flow deflector 50. The configuration of the lift generating section 36' is distinct from that of the blade 30 in Fig. 7. This configuration of blade with the flow deflector 50 generates an additional torque M_{D2}, that contributes to the power generated and it is due to the normal force F_{D2} created by the deflector 50.

[0017] Integrating the deflectors 50, 50' onto existing turbines, or incorporating their design into new turbines will increase the overall efficiency of the turbines. The deflectors may act as passive flow controllers, not requiring any additional control or monitoring equipment. By introducing the flow deflectors at several positions along the blade's length, the radial component of velocity of the incoming air flow may be redirected to produce an additional amount of torque on the rotor, thereby increasing the overall power produced by the turbine.

[0018] These and other advantages of the present invention will be apparent to those skilled in the art from the foregoing specification. Accordingly, it will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiments without departing from the invention as defined by the appended claims.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US20130224037A1 **[0005]**

Patentkrav

1. Airfoil-vingeenhed omfattende:

et vingeblad (30, 30'), der strækker sig i en radial retning fra en rod (40) imod en spids (42), idet vingebladet indeholder et opdriftsgenererende afsnit med et første profileret legeme (37) defineret mellem en trykoverflade (39) og en sugeoverflade (38), idet det første profilerede legeme (37) strækker sig fra en første forkant (31) til en første bagkant (33), idet en første korde strækker sig fra den første forkant (31) til den første bagkant (33) og er vinkelret på den radiale retning;

en flerhed af strømdeflektorer (50, 50'), som strækker sig langs mindst en af hhv. trykoverfladen (39) og sugeoverfladen (38) inden for det opdriftsgenererende afsnit af vingebladet i positioner med afstand til vingebladets (30, 30') første forkant (31) og i nærheden af vingebladets (30, 30') første bagkant (33), idet flerheden af strømdeflektorer (50, 50') definerer et andet profileret legeme (52), som strækker sig mellem en anden forkant (51) og en anden bagkant (53) med en anden korde, som strækker sig mellem den anden forkant (51) og den anden bagkant (53), idet det andet profilerede legeme (52) definerer en ydre overflade, som vender væk fra den respektive trykoverflade (39) eller sugeoverflade (38), langs hvilke flerheden af strømdeflektorer (50, 50') strækker sig;

hvor den anden korde, som strækker sig mellem den anden forkant (51) og den anden bagkant (53) af hver af flerheden af strømdeflektorer (50, 50') er proportional med den første korde, som strækker sig fra den første forkant (31) til den første bagkant (33) af vingebladet på stedet for hver af flerheden af strømdeflektorer (50, 50') langs mindst en af hhv. trykoverfladen (39) og sugeoverfladen (38), hvor den anden kordelængde af hver af flerheden af strømdeflektorer (50, 50') har en størrelse på mellem 1/8 og 1/2 af den første kordelængde af vingebladet på stedet for hver af flerheden af strømdeflektorer (50, 50'); og

hvor flerheden af strømdeflektorer (50, 50') er placeret langs en længde af vingebladet (30, 30'), sådan at en radial hastighedskomponent af en indkommende luftstrøm omdirigeres til at producere en yderligere mængde drejningsmoment på en rotor, hvorved den samlede effekt, der produceres af en turbine, som omfatter airfoil-vingeenheden, øges.

2. Airfoil-vingeenhed ifølge krav 1, hvor den anden korde ligger i en vinkel α på mellem -5° og 45° i forhold til den første korde.

3. Airfoil-vingeenhed ifølge krav 1, hvor den anden korde ligger i en vinkel α på mellem 0° og 15° i forhold til den første korde.

4. Airfoil-vingeenhed ifølge et af de foregående krav, hvor flerheden af strømdeflektorer (50, 50') er adskilt fra hinanden med en bestemt afstand.

5. Airfoil-vingeenhed ifølge krav 4, hvor den bestemte afstand er lig med en længde af den første korde.

6. Airfoil-vingeenhed ifølge et af de foregående krav, hvor flerheden af strømdeflektorer (50, 50') er placeret langs vingebladet mellem den første forkant (31) og den første bagkant (33).

7. Airfoil-vingeenhed ifølge et af de foregående krav, hvor det første profilerede legeme (37) har en første højde og det andet profilerede legeme (52) har en anden højde, og hvor den anden højde er mellem 1/10 til 1 af den første højde.

8. Airfoil-vingeenhed ifølge et af de foregående krav, hvor det første profilerede legeme (37) har en første højde og det andet profilerede legeme (52) har en anden højde, og hvor den anden højde er mellem 1/8 til 1/2 af den første højde.

9. Airfoil-vingeenhed ifølge et af de foregående krav, hvor det andet profilerede legeme (52) har en bredde, som er lig med cirka 1-10% af en længde af den første korde.

10. Airfoil-vingeenhed ifølge et af de foregående krav, hvor flerheden af strømdeflektorer (50, 50') er udført integreret med det første profilerede legeme (37).

11. Airfoil-vingeenhed ifølge et af kravene 1 til 9, hvor flerheden af strømdeflektorer (50, 50') er udført separat fra det første profilerede legeme (37) og fastgjort hertil.

12. Airfoil-vingeenhed ifølge et af kravene 1 til 9, hvor flerheden af strømdeflektorer (50, 50') er fastgjort til det første profilerede legeme (37) ved hjælp af dobbeltsidet luftfartstape eller

fladhovednitter.

13. Airfoil-vingeenhed ifølge et af kravene 1 til 9, hvor flerheden af strømdeflektorer (50, 50') er indstilleligt forbundet med det første profilerede legeme (37).

14. Airfoil-vingeenhed ifølge et af de foregående krav, hvor vingebladet (30, 30') har en kurvet konfiguration i planet.

15. Turbineenhed omfattende:

et nav (14) konfigureret til at rotere i en rotationsretning;

en flerhed af airfoil-vingeenheder ifølge et af de foregående krav, fastgjort til navenheden (114),

hvor flerheden af strømdeflektorer (50, 50') er konfigureret til at ændre den forekommende luftstrøm, sådan at der produceres ekstra kraft i rotationsretningen, og der genereres ekstra effekt.

DRAWINGS

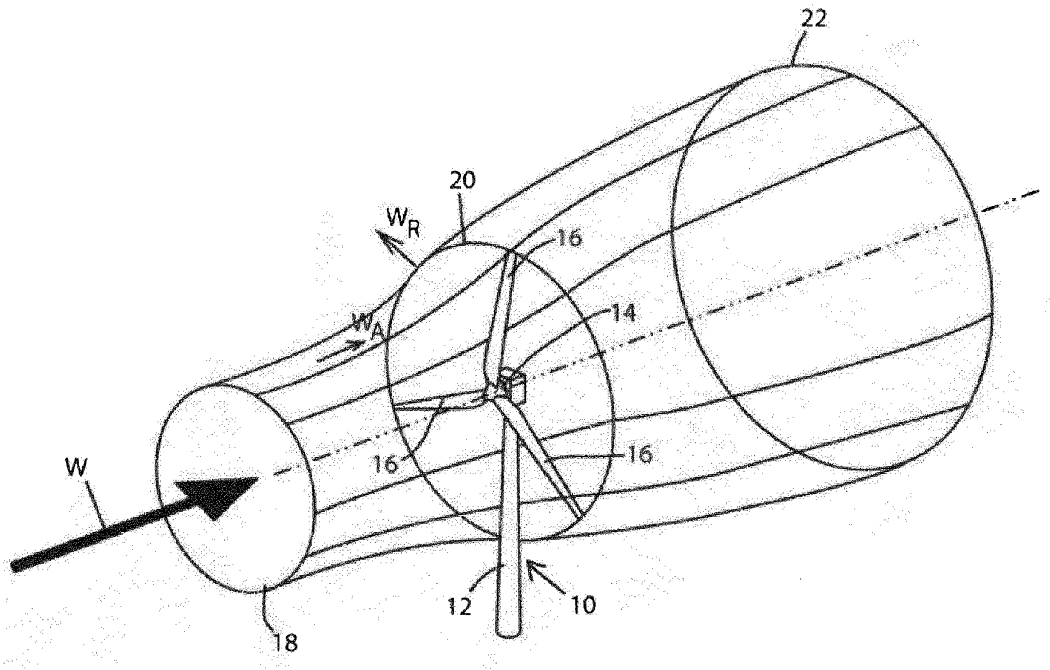


Fig. 1
(Prior Art)

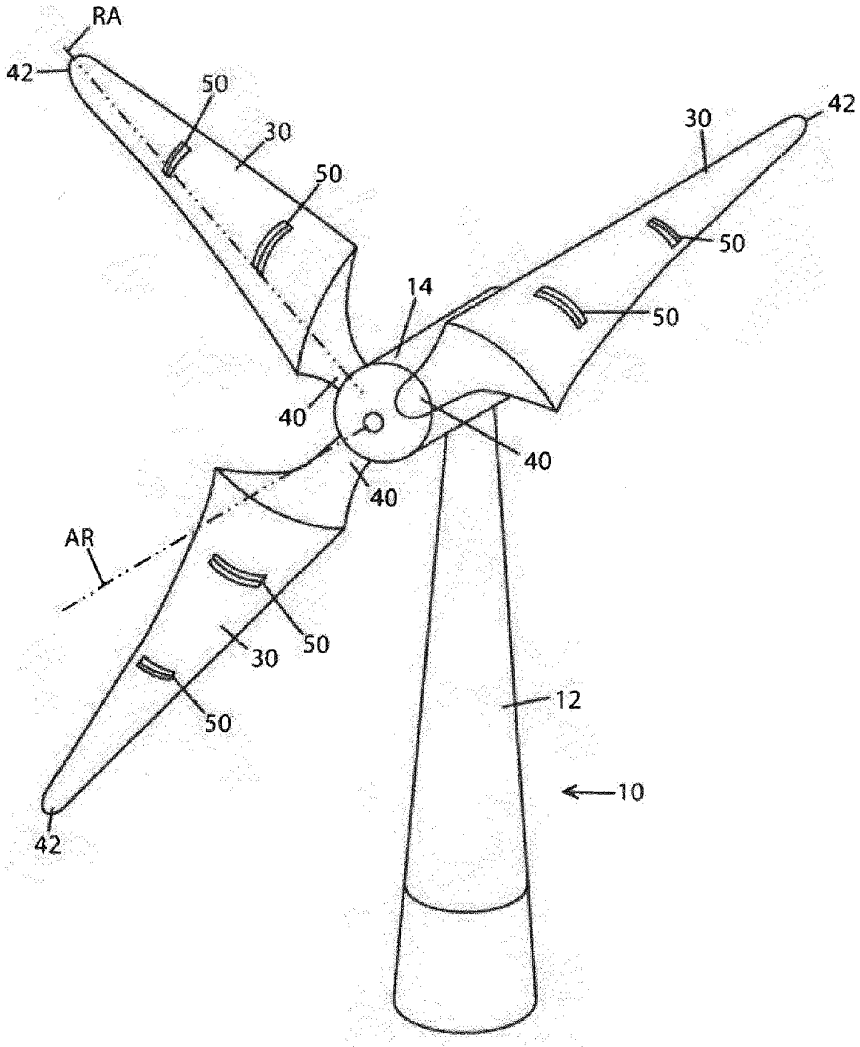


Fig. 2

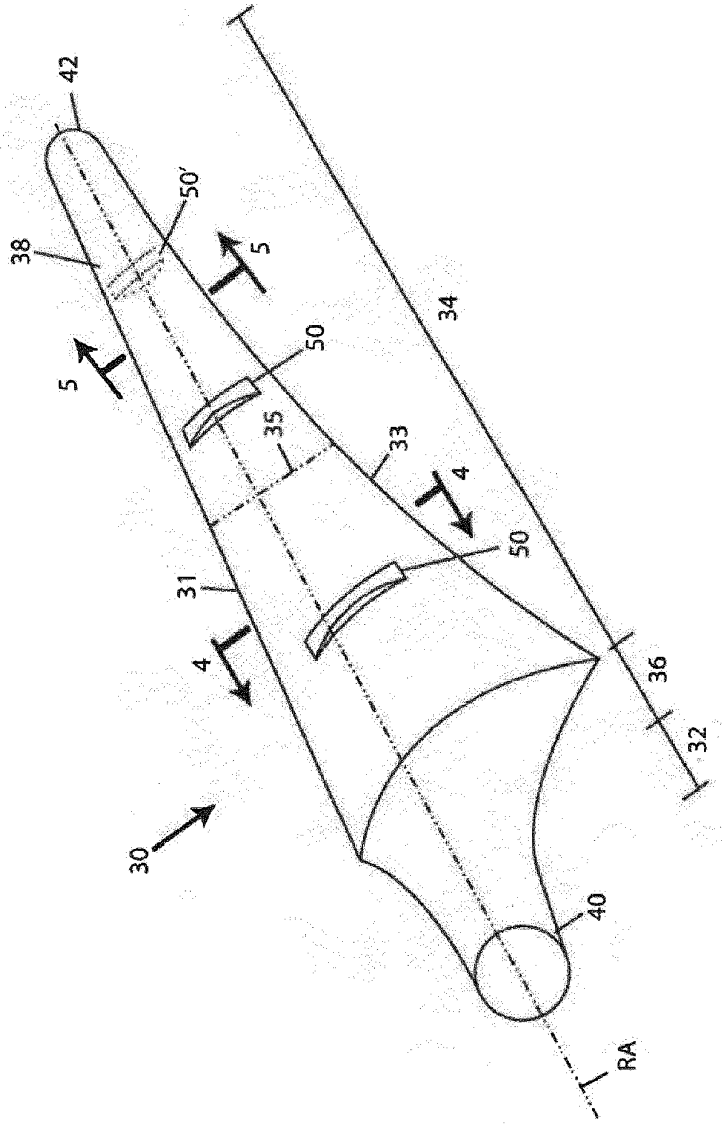


Fig. 3

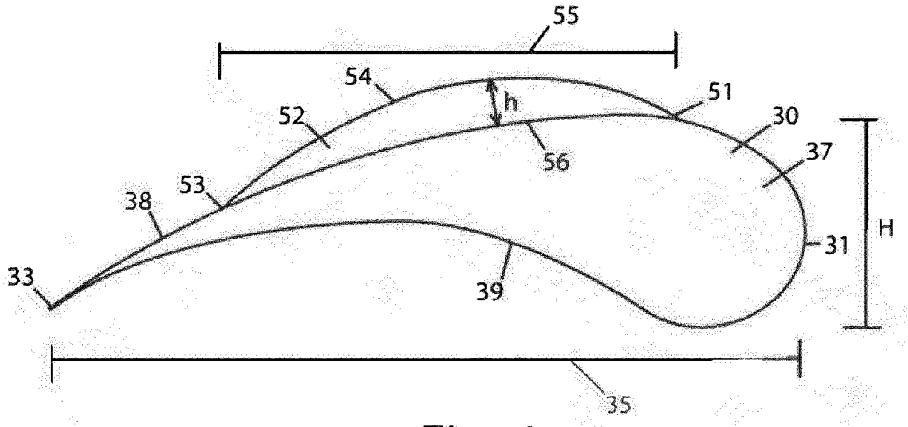

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Fig. 4

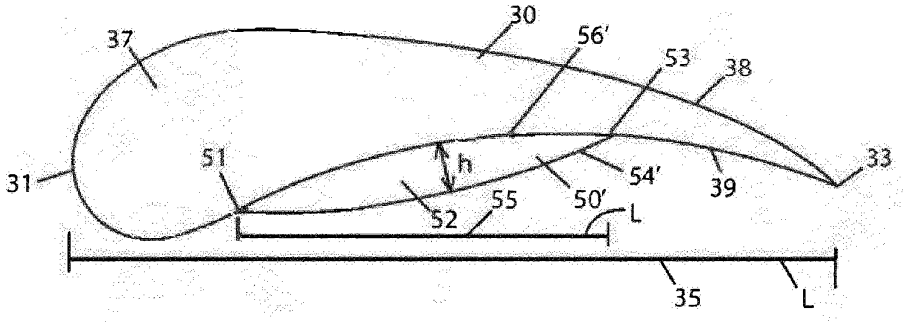

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Fig. 5

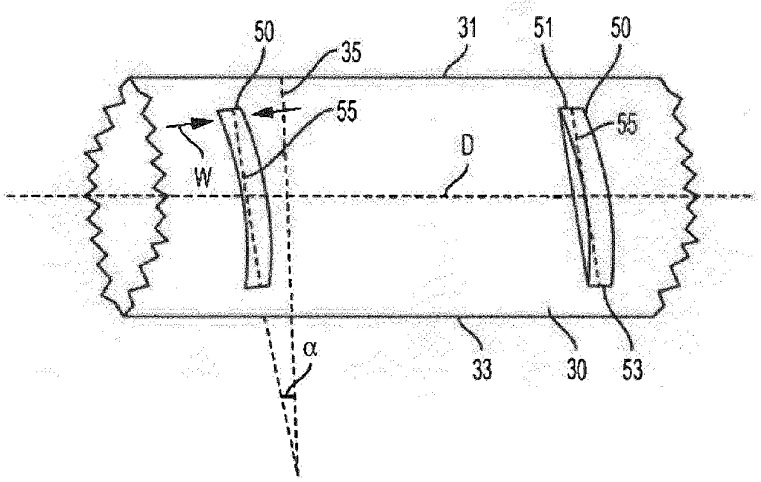


Fig. 6

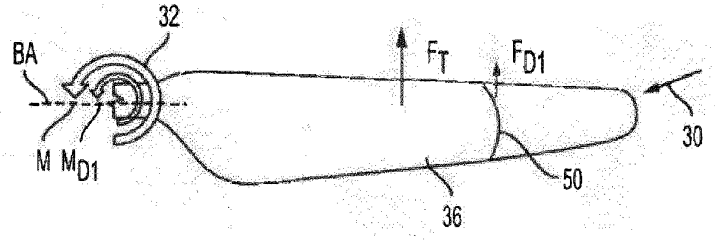


Fig. 7

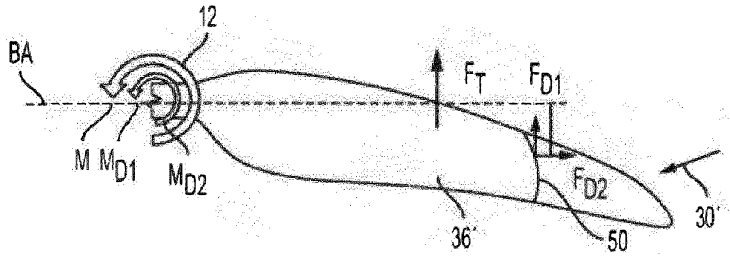


Fig. 8