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(71) Applicant *(for all designated States except US)*: **BELL HELICOPTER TEXTRON INC.** [US/US]; 600 E. Hurst Boulevard, Hurst, TX 76053 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **NARRAMORE, James, Charles** [US/US]; 2505 Rollingshire Court, Bedford, TX 76021 (US).

(74) Agents: **BARUFKA, Jack, S.** et al.; PILLSBURY WINTHROP SHAW PITTMAN LLP, P.O. Box 10500, McLean, VA 22102 (US).

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(54) Title: RETRACTABLE VORTEX GENERATOR

(57) Abstract: A flow control device is disclosed including a flow control surface (20) over which fluid is designed to flow in a predetermined direction (F) . Vortex generators (30) are associated with the flow control surface. Each respective vortex generator has a pivot axis (40) that forms an acute angle (a) with respect to the predetermined direction and is capable of being positioned in both of an extended state, in which the respective vortex generators function to create a swirling fluid flow, and a retracted state, in which the respective vortex generators are pivoted via the pivot axis so as to lie adjacent to the flow control surface. An actuator is associated with each of the vortex generators, each actuator adapted to position the associated vortex generator between the extended and retracted states. The flow control device is disclosed to be used in tiltrotor vehicles.

RETRACTABLE VORTEX GENERATOR

BACKGROUND OF THE INVENTION

Cross-Reference to Related Applications

[0001] This invention claims priority to U.S. Provisional Patent Application No. 60/695,181, filed on June 30, 2005, which is incorporated by reference in its entirety herein.

Field of the Invention

[0002] This invention relates to flow control surfaces with retractable vortex generators.

Description of Related Art

[0003] Vortex generators have been used with a variety of flow control surfaces to mix low momentum fluid flow associated with a boundary air layer of the flow control surface with a high momentum fluid flow outside of the boundary air layer. The use of such vortex generators in a variety of aircraft have produced improvements in maneuver effectiveness. However, permanently installed wing vortex generators produce drag penalties and may accrete foreign matter such as ice shapes that significantly degrade the proper performance of the aircraft.

[0004] Retractable vortex generators have been developed to compensate for these problems.

[0005] Bauer US 4,039,161, Cox US 5,253,828, and Lisy et al. US 6,105,904 each disclose vortex generators which may be retracted into a flow control surface. However, the retractable vortex generators described in these documents require modification of the structure on which it is disposed to allow for internal space into which the vortex generator may be retracted when not in use. This requirement for adequate space to accommodate the vortex generators may influence the design of the wing or other structure in a negative manner. This also requires that a wing, or other such structure having a flow control surface to which a vortex generator is desired to be added cannot be easily retrofitted for such vortex generators.

[0006] Campbell US 6,427,948, discloses a vortex generator which is capable of being selectively moved into a deflected position to produce downstream turbulence and moved into an undeflected position to reduce drag. The vortex generator of Campbell is formed of a shape memory alloy that is in the deflected position when no electric signal is applied to an associated heater and is in the undeflected position when an electric signal is applied to the associated heater. However in both the deflected and undeflected states the vortex generator protrudes outside of the flow control surface and, while the undeflected state

may produce less drag in comparison with the deflected state, the protrusion will still produce some undesirable residual drag and does not alleviate the problem of ice accretion on the exposed vortex generators.

BRIEF SUMMARY OF THE INVENTION

[0007] The present invention provides a flow control device including a flow control surface over which fluid is designed to flow in a predetermined direction. Vortex generators are associated with the flow control surface. Each respective vortex generator has a pivot axis that forms an acute angle with respect to the predetermined direction and is capable of being positioned in both of an extended state, in which the respective vortex generators function to create a swirling fluid flow, and a retracted state, in which the respective vortex generators are pivoted via the pivot axis so as to lie adjacent to the flow control surface. An actuator is associated with each of the vortex generators, each actuator is adapted to position the associated vortex generator between the extended and retracted states.

[0008] In one embodiment, the acute angle that the vortex generators make with the predetermined direction is between 5 to 45 degrees when in the extended state.

[0009] In one example, the actuator may be a heater that actuates a shape memory material made from a nickel-titanium alloy. However other types of electromechanical actuators may also be used.

[0010] In one example, the vortex generator may be in the form of a fin that is parallel to the flow control surface when in the retracted state and set at an angle between 0 and 180 degrees when in the extended state.

[0011] The flow control device as described provides reduction of drag and ice accumulation on flow control surfaces without requiring space in the flow control device to be reserved for the retracted vortex generators. Thus the retractable vortex generators of the current invention may be applied to a large variety of flow control surfaces without the necessity of extensive retrofitting of the flow control surfaces.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1A is a side view of a flow control device having a vortex generator in an extended or deployed state in accordance with the present invention.

[0013] FIG. 1B is a top view of a flow control device having a vortex generator in an extended or deployed state in accordance with the present invention.

[0014] FIG. 2A is a side view of a flow control device having a vortex generator in a retracted state in accordance with the present invention.

[0015] FIG. 2B is a top view of a flow control device having a vortex generator in a retracted state in accordance with the present invention.

[0016] FIG. 3A is a view along a pivot axis of a respective vortex generator when in the retracted state in accordance with one embodiment of the present invention.

[0017] FIG. 3B is a view along a pivot axis of the vortex generator of FIG. 3A when in an extended or deployed state.

[0018] FIG. 4A is a view along a pivot axis of a respective vortex generator when in the retracted state in accordance with another embodiment of the present invention.

[0019] FIG. 4B is a view along a pivot axis of the vortex generator of FIG. 4A when in an extended or deployed state.

DETAILED DESCRIPTION OF THE INVENTION

[0020] FIG. 1A, 1B, 2A, and 2B show an example of a flow control device **10** in accordance with one embodiment of the present invention. FIG. 1A shows a side view and FIG. 1B shows a top view of a flow control surface **20** over which a fluid media is designed to flow in a direction represented by vector **F**. An array of vortex generators **30** are illustrated in an extended position. Vortex generators 30 are substantially flat structures that are generally perpendicular with respect to the plane of the control surface when extended. Each of the vortex generators **30** are constructed so as to be pivotable about a pivot axis **40**. The pivot axis **40** forms an acute angle α with the flow direction (or primary wind direction) **F** so as to facilitate the generation of a swirling fluid flow. The acute angle α may be between 5 and 45 degrees (or -5 to -45 degrees, depending on the direction measured) to generate vortices over the flow control surface **20**. In a more specific embodiment, the angle α is between 12 and 25 degrees, and even more specifically between 19 and 21 degrees. FIG. 2A and 2B show a side view and a top view of a flow control surface **20** over which a fluid media is designed to flow in the predetermined direction **F** when an array of vortex generators **30** are in a retracted position. As shown the vortex generators have pivoted about pivot axis **40** so as to lie in generally parallel, overlying relation with the upper flow control surface **20**. In one embodiment, the retracted vortex generators lie in abutting contact with the upper flow control surface **20**. In this state the vortex generators are out of the way of the flow thus substantially eliminating drag effects from the vortex generators. Thus the vortex generators are extended when needed and retracted at all other flight conditions without requiring any space in the flow control device for storing the vortex generator when not in use. In the illustrated embodiments, surface 20 has a substantially continuous, unmodified

shape. It can be appreciated, therefore, that the vortex generators as illustrated in the FIGS. herein can be retrofitted onto many different types of previously manufactured surfaces 20. In another embodiment (not shown), the upper surface area on which the vortex generator is disposed when deployed is slightly recessed. Such a recess may have a depth that is of the same dimension as the thickness of the vortex generator, so that the vortex generator's exposed surface when retracted is substantially flush with adjacent surface portions of surface 20.

[0021] FIG. 3A and 3B show an example of the operation of a vortex generator **30** on the flow control surface **20** in accordance with one embodiment of the invention. FIG. 3A is a view taken in a direction along the pivot axis **40** of the vortex generator **30** when it is in the retracted state. FIG. 3B is a view along to the pivot axis **40** of the vortex generator **30** when it is in extended state. The vortex generator is actuated by a motor or actuator **50** so as to be repositioned between the retracted and extended state. The extended state may be variably chosen so that the vortex generator is inclined at an angle θ with respect to the flow control surface **20**. In the current embodiment the actuator **50** may be an electromagnetic motor controlled by electrical input **60** (from an external controller) and the angle θ may be adjusted to lie between 0 and 180 degrees relative to surface 20. In one embodiment the angle θ is deployed at an orientation or angle θ that is normal (90°) to surface 20. In another embodiment, the vortex 30 is deployed at an angle of -4° to +4° relative to normal.

[0022] FIG. 4A and 4B show an example of another actuator for positioning the vortex generator **30** between the extended and retracted position. In this example the actuator includes a heater **70** controlled by electrical input **80** (from an external controller). The vortex generator **30** is formed with a shape memory alloy such as nickel-titanium alloys and is initially deformed to be in the extended position as shown in FIG. 4B during manufacture. In the extended position of FIG. 4B, the vortex generator **30** forms an angle θ with respect to surface **20**. the angle θ can be in the same range or ranges as that for the embodiment of FIGS. 3A and 3B as discussed above. Upon application of heat by the heater **70** above the particular transition temperature of the shape memory material, the vortex generator returns to the non-deformed state as shown in FIG. 4A. In another embodiment, the shape memory alloy vortex generator is initially in a retracted (non-deployed) position as illustrated in FIG. 4A. When heat is applied to the shape memory alloy vortex generator it moves from its retracted position of FIG. 4A to the deployed position of FIG. 4B.

[0023] A variety of types of actuators may be used to perform the pivoting function as described as evident to a person of ordinary skill in the art. For example thermal bimorph actuators, piezoelectric bimorph actuators as well as any other actuators capable of creating a pivoting action may be employed as the actuators of the present invention.

[0024] In one embodiment, the flow control device of the present invention is employed as part of a wing of a tiltrotor aircraft.

[0025] Although a particular configuration of the vortex generators has been shown, the present invention is not limited to this configuration and a variety of other arrangements may be used in creating co-rotating as well as counter-rotating effects.

[0026] Although the shape of the individual vortex generators has been shown as triangular, the present invention is not limited to this shape and other shapes of the vortex generator such as rectangular shapes or other shapes may be used.

[0027] While a particular embodiment of the present invention has been shown and described, it will be apparent to those skilled in the art that a variety of modifications may be made without departing from the teachings of the present invention.

WHAT IS CLAIMED IS:

1. A flow control device comprising:

a flow control surface over which fluid is designed to flow in a predetermined direction;

vortex generators associated with the flow control surface, each respective vortex generator having a pivot axis that forms an acute angle with respect to the predetermined direction and capable of being positioned in both of an extended state, in which the respective vortex generators function to create a swirling fluid flow, and a retracted state, in which the respective vortex generators are pivoted via the pivot axis so as to lie adjacent to the flow control surface; and

an actuator associated with each of the respective vortex generators, each actuator adapted to position the associated vortex generator between the extended and retracted states.

2. A flow control device according to claim 1, wherein the acute angle is from 5 to 45 degrees.

3. A flow control device according to claim 1, wherein the vortex generators are formed of a shape memory material, and wherein the actuator includes a heater that actuates the shape memory material.

4. A flow control device according to claim 1, wherein each of the respective vortex generators is in the form of a fin that lies parallel to the flow control surface when in the retracted state and is set at an angle greater than 0 degrees and less than 180 degrees with respect to the flow control surface when in the extended state.

5. A flow control device according to claim 1, wherein the flow control surface is part of a tiltrotor vehicle.

6. An aircraft comprising:

a tiltrotor wing;

a flow control surface formed on the tiltrotor wing over which fluid is designed to flow in a predetermined direction;

vortex generators associated with the flow control surface, each respective vortex generator having a pivot axis that forms an acute angle with respect to the predetermined direction and capable of being positioned in both of an extended state, in which the respective vortex generators function to create a swirling fluid flow, and a retracted state, in which the respective vortex generators are pivoted via the pivot axis so as to lie adjacent to the flow control surface; and

an actuator associated with each of the respective vortex generators, each actuator adapted to position the associated vortex generator between the extended and retracted states.

7. An aircraft according to claim 6, wherein the acute angle is from 5 to 45 degrees.

8. An aircraft according to claim 6, wherein the actuator includes a heater and wherein the vortex generators comprise a shape memory material that can be moved based on actuation of the heater.

9. An aircraft according to claim 6, wherein each of the respective vortex generators is in the form of a fin that lies parallel to the flow control surface when in the retracted state and is set at an angle greater than 0 degrees and less than 180 degrees with respect to the flow control surface when in the extended state.

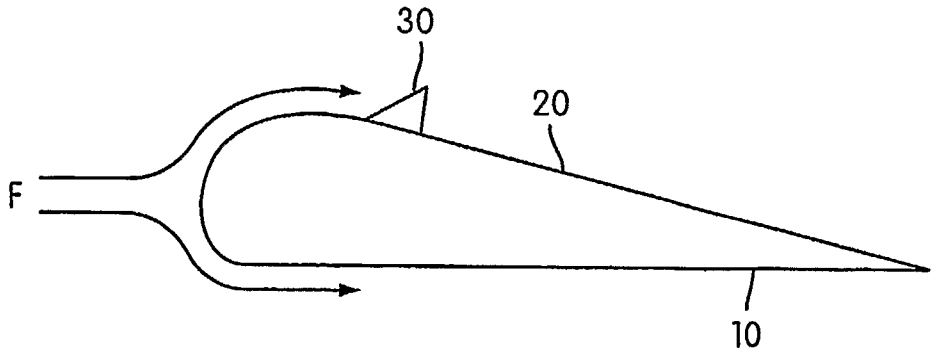


FIG. 1A

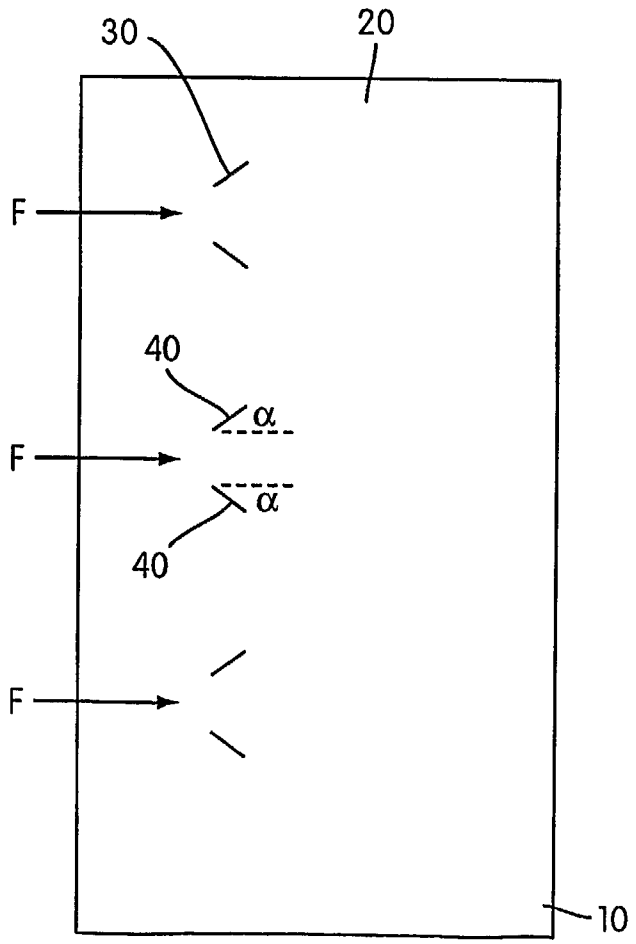


FIG. 1B

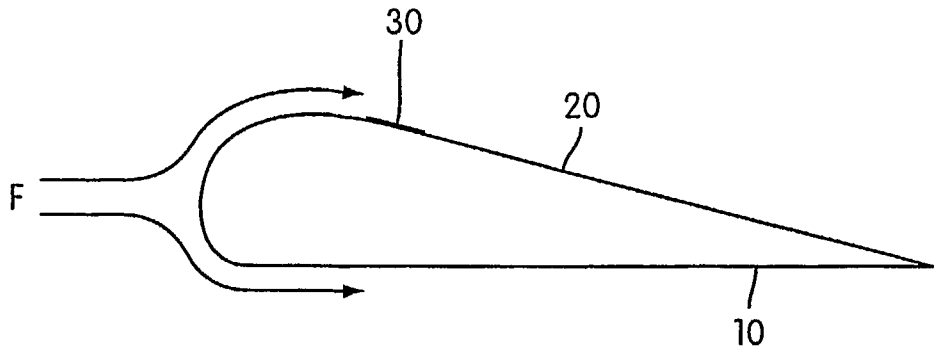


FIG. 2A

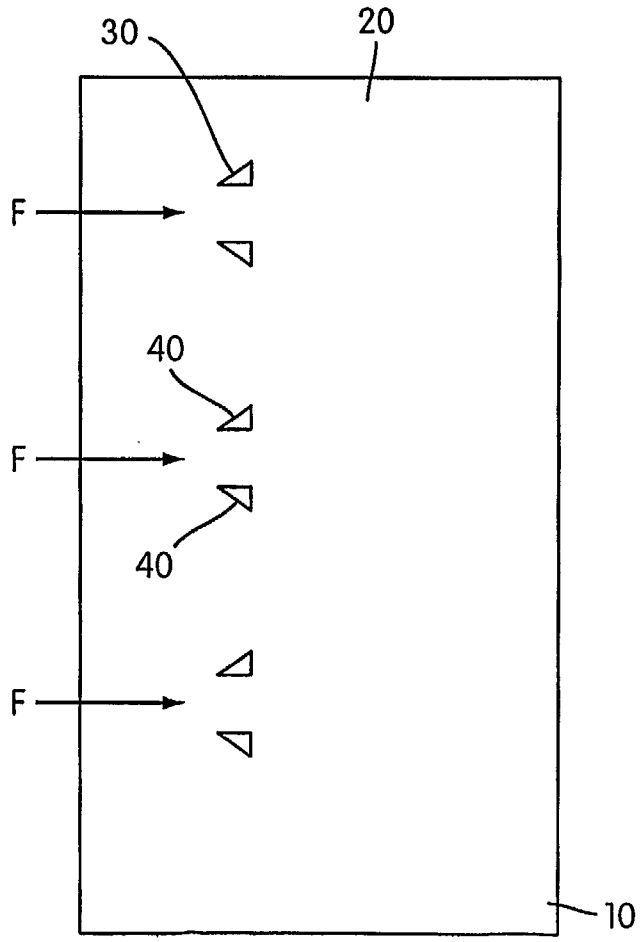


FIG. 2B

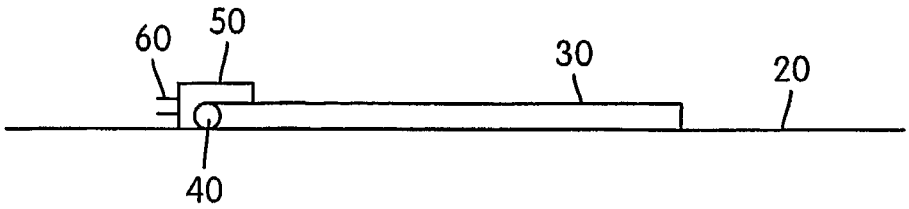


FIG. 3A

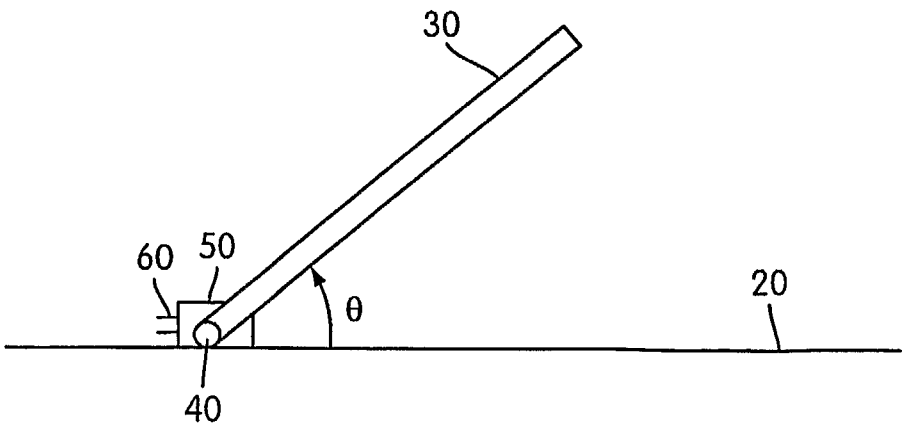


FIG. 3B

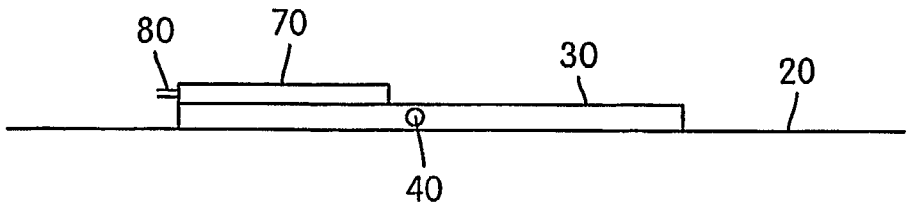


FIG. 4A

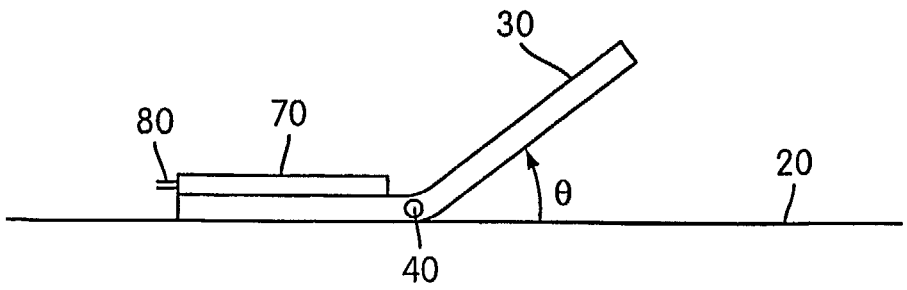


FIG. 4B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/025730

A. CLASSIFICATION OF SUBJECT MATTER
INV. B64C23/06

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

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 practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 105 904 A (LISY FREDERICK J [US] ET AL) 22 August 2000 (2000-08-22) cited in the application figures 1,2	1,2,4-7, 9
Y	US 4 739 957 A (VESS ROBERT J [US] ET AL) 26 April 1988 (1988-04-26) figures 1-5	1,2,4-7, 9
Y	US 4 466 586 A (BURNHAM ROBERT W [US]) 21 August 1984 (1984-08-21) figures 1-4	1,2,4-7, 9
A	US 6 427 948 B1 (CAMPBELL MICHAEL [US]) 6 August 2002 (2002-08-06) cited in the application abstract	1,3,6,8

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 November 2006	22/11/2006

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, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Pedersen, Kenneth

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2006/025730

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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