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(54) **ELASTICALLY DEFORMABLE SIDE-EDGE LINK FOR TRAILING-EDGE FLAP AEROACOUSTIC NOISE REDUCTION**

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(51) **Int. Cl.**

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B64C 5/10	(2006.01)
B64C 3/52	(2006.01)

(52) **U.S. Cl.**
USPC **244/213**; 244/212; 244/215; 244/218

(58) **Field of Classification Search**
USPC 244/211–215, 218, 219
See application file for complete search history.

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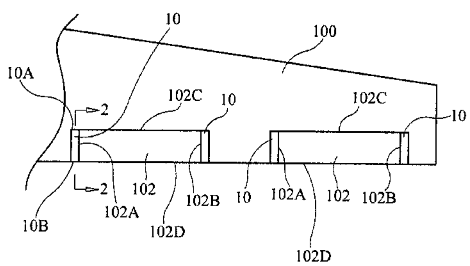
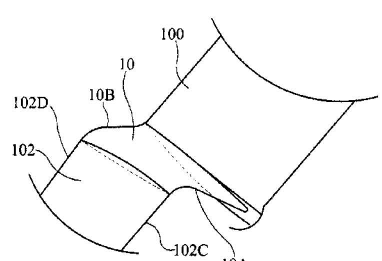
(57) **ABSTRACT**

A system is provided for reducing aeroacoustic noise generated by an aircraft having wings equipped with trailing-edge flaps. The system includes a plurality of elastically deformable structures. Each structure is coupled to and along one of the side edges of one of the trailing-edge flaps, and is coupled to a portion of one of the wings that is adjacent to the one of the side edges. The structures elastically deform when the trailing-edge flaps are deployed away from the wings.

11 Claims, 2 Drawing Sheets





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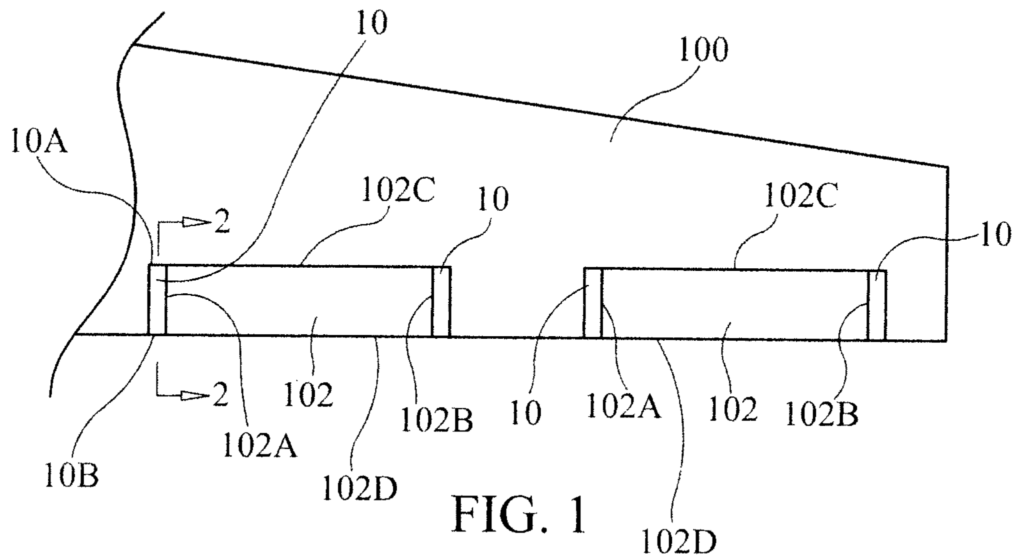
10
100
10A
102C
10
102C
10
2
2
102
102B
10
102A
102
102B
10B
102A
102D
102D

FIG. 1

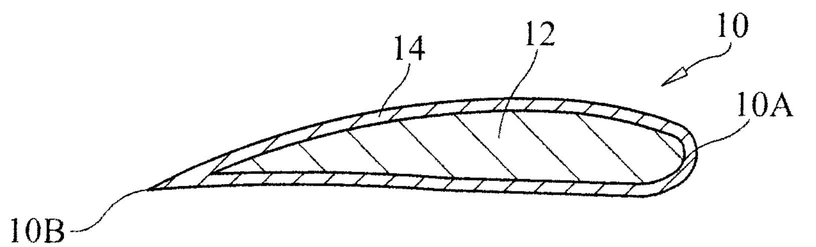
14
12
10
10A
10B

FIG. 2

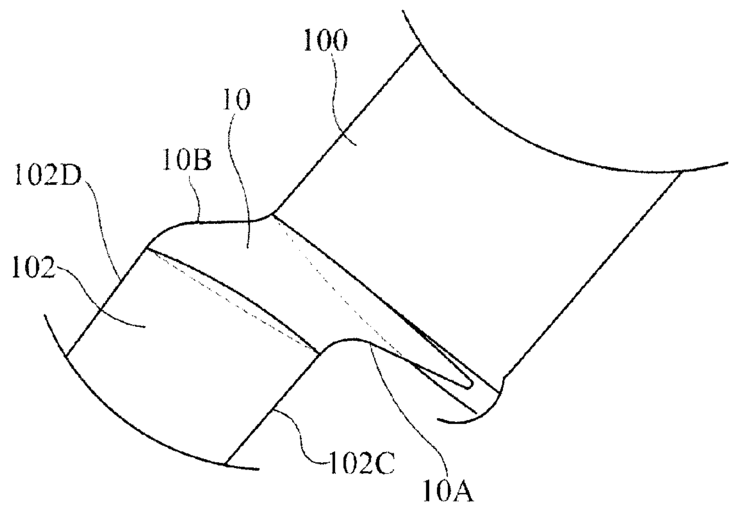
100
10
10B
102D
102
102C
10A

FIG. 3

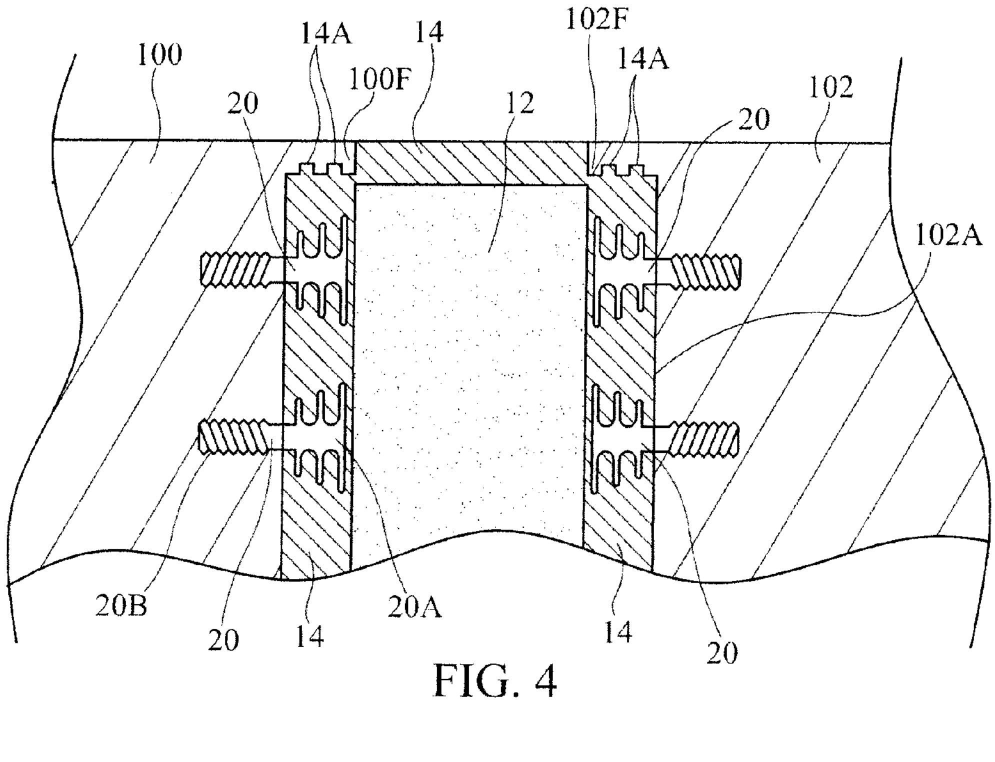
14A
14
102F
14A
100
100F
102
20
12
20
102A
20B
20
14
20A
14
20

FIG. 4

ELASTICALLY DEFORMABLE SIDE-EDGE LINK FOR TRAILING-EDGE FLAP AEROACOUSTIC NOISE REDUCTION

Pursuant to 35 U.S.C. §119, the benefit of priority from provisional application 61/423,350, incorporated by reference herein in its entirety, with a filing date of Dec. 15, 2010, is claimed for this non-provisional application.

ORIGIN OF THE INVENTION

This invention was made in part by employees of the United States Government and may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to aeroacoustic noise reduction. More specifically, the invention is a system for reducing aeroacoustic noise originating at opposing side edges of trailing-edge flap components of aircraft high-lift systems.

2. Description of the Related Art

Conventional transport aircraft wing design is driven mainly by cruise efficiency, i.e., adequate lift is generated at high speed for level flight with minimal drag. Conventional high-lift systems using leading-edge slats and trailing-edge flaps were designed to augment lift and improve stall characteristics at the low speeds required during landing. These multi-element airfoil systems increase the effective chord (i.e., stream-wise dimension) of the wing and thus its effective area. The major effect of the multi-element airfoil arrangement is to generate a much larger pressure difference (lift) between the upper (suction) and lower (pressure) surfaces than would be possible via a single airfoil element.

The multi-element airfoil forms a smooth single-element profile during the cruise phase of flight to reduce wing drag. That is, the multiple airfoil elements are nested together in the retracted position. However, when deployed, the multi-element implementation of the high-lift system presents many discontinuities and other unfavorable, geometric features responsible for producing flow unsteadiness, and thus noise. The principal geometric features for producing flow unsteadiness at an airfoil's trailing edge are the side edges of flaps.

Existence of a strong pressure, differential between the bottom and top surface of the flap results in the formation of a complex dual-vortex system. More specifically, near the flap leading edge, the boundary layer on the bottom surface separates at the sharp corner and roils up to form the stronger of the two vortices. Similarly, the thin boundary layer on the side edge separates at the sharp top corner and forms what is initially the weaker of the two vortices. Both vortices gain strength and size along the flap chord because of the constant ingestion of vorticity. Downstream of the flap mid-chord, the side vortex begins to interact and merge with the vortex on the top surface. Eventually, a single dominant stream-wise vortex is formed. Considerable flow unsteadiness (i.e., noise source) is produced during the shear layer roil up, vortex formation, and vortex merging process as well as by the interaction of the vortices with the sharp corners at the flap edge.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a system for reducing aeroacoustic noise originating at the side edges of a deployed trailing-edge flap.

Another object of the present invention is to provide a system for reducing aeroacoustic noise at the side edges of a flap without compromising an aircraft's cruise efficiency, lift, and stall characteristics at landing.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

In accordance with the present invention, a system is provided for reducing aeroacoustic noise generated by an aircraft having wings equipped with trailing-edge flaps. Each of the trailing-edge flaps includes opposing side edges that nest within one of the wings prior to deployment of the trailing-edge flaps. The system includes a plurality of elastically deformable structures. Each structure is coupled to and along one of the side edges of one of the trailing-edge flaps, and is coupled to a portion of one of the wings that is adjacent to the one of the side edges. The structures elastically deform when the trailing-edge flaps are deployed away from the wings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of the top of an aircraft wing equipped with trailing-edge flaps and elastically-deformable flap side-edge links in accordance with an embodiment of the present invention;

FIG. **2** is a cross-sectional view of a side-edge link in accordance with an embodiment of the present invention as taken along line **2-2** in FIG. **1**;

FIG. **3** is a perspective view of a deployed flap illustrating a side-edge link in its elastically deformed configuration; and

FIG. **4** is a cross-sectional view of a portion of an elastically deformable link coupled to a wing and flap's side edge using a plurality of fir tree fasteners in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings and more particularly to FIG. **1**, a plan view of the top of an aircraft wing **100** is shown. Wing **100** includes one or more trailing-edge flaps **102** that nest totally or substantially within wing **100** to form a smooth profile that is maintained during the cruise phase of flight as would be understood in the art. The number, size, shape, etc., of flaps **102** are not limitations of the present invention. Further, the mechanisms used to deploy and retract flaps **102** are not limitations of the present invention and will, therefore, be omitted from the instant description and drawings. Still further, the presence or absence of leading edge slats (not shown) does not affect the present invention.

Disposed at opposing side edges (or "sides" as it will also be referred to herein) **102**A and **102**B of each flap **102** is an elastically deformable link **10**. In general, each link **10** is attached to one of sides **102**A and **102**B and to a portion of wing **100** that is adjacent to the corresponding one of sides **102**A and **102**B. As will be explained further below, when flaps **102** are deployed (i.e., pushed out and way from their nested position with wing **100** as is understood in the art), each link **10** is capable of elastic deformation. At flap deployment, link **10** simultaneously elongates in a chord-wise direction, bends, and twists to essentially bridge the gap between a corresponding one of sides **102**A and **102**B and the corresponding regions of wing **300** that sides **102**A and **102**B nest within when flaps **102** are retracted for the cruise phase of flight. At flap retraction, link **10** elastically returns to its pre-deployment state along with the flap.

Each elastically deformable link **10** must satisfy a number of diverse criteria. Specifically, each link **10** must not affect the aerodynamic efficiency of wing **100** in the cruise phase of flight. That is, in the cruise phase of flight when flaps **102** are not deployed (i.e., typically retracted into wing **100**), each link **10** should substantially match the chord-wise cross-sectional shape of the flap's side edge and the portion of the wing where the link is attached. In addition, each link **10** must be capable of deforming by a sufficient amount to support full deployment of flap **102** while possessing elastic properties that allow the link to return to its "substantially matched shape" when flap **102** is retracted. Still further, each link must be capable of being deformed during flap deployment without overburdening the flap deployment actuators. Each link **10** must also be able to sustain the aerodynamic load presented to it in its deployed and retracted configurations. Furthermore, each link **10** is ideally a simple passive device/structure that minimizes weight, complexity, and cost impact on the overall aircraft design.

In addition, to the above-noted criteria, if each link subtends minimum span-wise extent, the links will have a minimal effect on flap area available for producing lift. The desirable consequences of this criterion are many. The link does not need to produce lift. Thus, the link structure will be lightly loaded by the aerodynamic flow. Light aerodynamic load allows a very compliant link design that, in turn, supports the other criteria described above. Furthermore, the precise shape of the deployed link is not as critical as it would be if lift production were a requirement. Thus, the link design can be greatly simplified, thereby also reducing cost and weight.

Given the above criteria, each link **10** can be made from elastomeric materials(s) and aerodynamically shaped to conform to the profile of wing **100** when flaps **102** are stowed therein for the cruise phase of flight. For example, each link **10** can be shaped as a chord-wise segment of flap **102** thereby essentially forming an extension of one of sides **102**A and **102**B. In other words, with flaps **102** in their stowed/retracted position, each link **10** can be matched (or substantially matched) to a chord-wise cross-section of flap **102** at side **102**A or side **102**B, and matched (or substantially matched) to the shape of wing **100** where it is coupled thereto.

By way of example, a cross-section of an elastically deformable link **10** is shown in FIG. **2**. In the illustrated embodiment, link **10** is shaped like an airfoil (e.g., matching the airfoil shape of the flap to which it will be coupled) with a leading edge **10**A aligned with the leading edge **102**C of flap **102** and with a trailing-edge **10**B aligned with the trailing-edge **102**D of flap **102**. To increase the elastic deformability of link **10** while decreasing the force needed to deform link **10** as well as decreasing the weight thereof, link **10** can be constructed with an elastomeric foam core **12** encased by a nonporous elastomeric skin **14**. The base elastomer(s) used to form core **12** and nonporous skin **14** can be the same or different without departing from the scope of the present invention. The choice of elastomer(s) in the present invention will be dictated by the mechanical requirements of a particular application. By way of examples, a suitable elastomeric foam is the Flex-Foam-iT series available commercially from Smooth-On, Inc., and a suitable elastomeric skin is EP1150 commercially available from Eager Plastics, Inc.

Foam core **12** and skin **14** can be distinctly delineated (as shown). However, the present invention is not so limited as link **10** could also be constructed such that foam core **12** gradually blends or changes into nonporous skin **14**. The delineation between foam and skin or the blending of foam-to-skin can be accomplished during the fabrication of link **10** where the particular choice of fabrication is not a limitation of the present invention.

As mentioned above, when flaps **102** are deployed away from wing **100** as is known in the art, each link **10** elastically deforms at flap side edges **102**A and **102**B to fill the gap formed between each flap side edge and the portion of the wing adjacent thereto. FIG. **3** illustrates one link **10** in its deformed state as flap **102** is deployed away from wing **100**. With link **10** so-deformed, link **10** delays pressure equalization of the air moving over and under the wing thereby relegating the roll-up process and vortex formation to a region that is well downstream of the flap's trailing edge. As a result, the unsteady interaction of the vortical flow with the sharp edges at the flap's tips is eliminated. It has been shown both computationally and experimentally that the present invention's approach to the flap side-edge virtually eliminates one noise production mechanisms at the flap's side edges. At the same time, the link is confined to a very short spanwise extent so that the structure is subjected to minimal lift loads.

The coupling of each link **10** to a corresponding flap side edge and adjacent wing portion can be accomplished in a variety of ways without departing from the scope of the present invention. By way of example, FIG. **4** illustrates the use of structure-engagement fittings **14**A and a number of fir tree fasteners **20** to mechanically couple link **10** to wing **100** and flap **102** at (for example) side edge **102**A. More specifically, each fastener's head **20**A is captured in link **10** (e.g., retained in skin **14** as shown) and each fastener's threaded end **20**B is screwed into either wing **100** or flap **102**. Coupling of link **10** no wing **100** and flap **102** can be further enhanced by having skin **14** define fittings **14**A around the edges thereof for compressed/fitted engagement with corresponding fittings **100**F and **102**F formed/provided on wings **100** and flap **102**, respectively. The mechanical coupling could also include hard mounting plates/assemblies (not shown) for use in combination with (or in place of) fasteners **20**. Still further, other types of fasteners/mounting systems can be used without departing from the scope of the present invention.

The advantages of the present invention are numerous. The elastically deformable links offer a simple, lightweight, and cost effective solution to aeroacoustic noise originating at the side edges of a deployed flap. The links can be configured to subtend minimal spanwise extent so that the lift production from the flap is relatively unaffected. Moreover, the links are not required to sustain aerodynamic lift, thereby greatly relaxing the geometric constraints on the link and simplifying the design. The links can blend with a wing's aerodynamic shape for the cruise phase of flight. The links are readily deformed when a flap is deployed but elastically returned to their aerodynamic shape when the flap is retracted. The links could be retro-fitted to existing aircraft and readily incorporated into new aircraft designs.

Although the invention has been described relative to a specific embodiment thereof, there are numerous variations and modifications that will be readily apparent to those skilled in the art in light of the above teachings. In is therefore to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A system for reducing aeroacoustic noise generated by an aircraft having wings equipped with trailing-edge flaps wherein each of the trailing-edge flaps includes opposing side edges that nest within one of the wings prior to deployment of the trailing-edge flaps, said system comprising:

a plurality of elastically deformable structures, each of said structures adapted to be coupled only at peripheral edges thereof (i) to and along one of the side edges of one of the trailing-edge flaps, and (ii) to a portion of one of the wings adjacent to the one of the side edges, each of said structures defined only by elastomeric material between said peripheral edges,

wherein said structures elastically deform when the trailing-edge flaps are deployed away from the wings.

2. A system as in claim **1**, wherein each of said structures comprises an aerodynamic shape.

3. A system as in claim **1** wherein, prior to being elastically deformed, each of said elastically deformable structures is shaped as a chord-wise segment of an airfoil.

4. A system as in claim **1**, wherein each of said structures comprises:

an elastomeric foam; and

a non-porous elastomeric skin encasing said elastomeric foam and defining said peripheral edges.

5. A system as in claim **4**, wherein each of said structures comprises an aerodynamic shape.

6. A system as in claim **4** wherein, prior to being elastically deformed, each of said structures is shaped as a chord-wise segment of an airfoil.

7. A system for reducing aeroacoustic noise generated by an aircraft having wings equipped with trailing-edge flaps wherein each of the trailing-edge flaps includes opposing side edges that nest within one of the wings prior to deployment of the trailing-edge flaps, said system comprising:

a plurality of elastically deformable structures, each of said structures formed by an elastomeric foam encased in a non-porous elastomeric skin; and

a mounting system for coupling only said elastomeric skin of each of said structures to and along one of the side edges of one of the trailing-edge flaps, and adapted to be coupled to a portion of one of the wings adjacent to the one of the side edges, wherein only said elastomeric foam defines a spanwise extent for each of said structures between peripheral edges of said elastomeric skin,

wherein said structures elastically deform when the trailing-edge flaps are deployed away from the wings.

8. A system as in claim **7**, wherein each of said structures comprises an aerodynamic shape.

9. A system as in claim **7** wherein, prior to being elastically deformed, each of said elastically deformable structures is shaped as a chord-wise segment of an airfoil.

10. A system for reducing aeroacoustic noise generated by an aircraft having wings equipped with trailing-edge flaps wherein each of the trailing-edge flaps includes opposing side edges that nest within one of the wings prior to deployment of the trailing-edge flaps, said system comprising:

a plurality of elastically deformable structures, each of structures adapted to be coupled only at peripheral edges thereof (i) to and along one of the side edges of one of the trailing-edge flaps while substantially matching a chord-wise cross-section thereof prior to deployment of the trailing-edge flaps, and (ii) to a portion of one of the wings adjacent to the one of the side edges white substantially matching a chord-wise cross-section of said portion prior to deployment of the trailing-edge flaps, each of said structures defined only by elastomeric material between said peripheral edges,

wherein said structures elastically deform when the trailing-edge flaps are deployed away from the wings.

11. A system as in claim **10**, wherein each of said structures comprises:

an elastomeric foam; and

a non-porous elastomeric skin encasing said elastomeric foam and defining said peripheral edges.

* * * * *