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.
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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 rolls 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 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 roll 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.

Dispersed at opposing side edges (or “sides” as it will also be referred to herein) 102A and 102B of each flap 102 is an elastically deformable link 10. In general, each link 10 is attached to one of sides 102A and 102B and to a portion of wing 100 that is adjacent to the corresponding one of sides 102A and 102B. 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 the corresponding regions of wing 300 that sides 102A and 102B 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 being deformed during deployment without overburdening the 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 allows a very compliant link design that, in turn, supports a new 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 14A and a number of fir tree fasteners 20 to mechanically couple link 10 to wing 100 and fastener 20. More specifically, each fastener’s head 20A is captured in link 10, retained in skin 14 as shown) and each fastener’s threaded end 20B 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 14A around the edges thereof for compressed/fitted engagement with corresponding fittings 100F and 102F formed/provided on wings 100 and flap 102, respectively. The mechanical coupling could also include hard mounting plates/assembly (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 subambient 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 retrofitted 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 trail-
ing-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 struc-
tures between peripheral edges of said elastomeric skin, 
wherein said structures elastically deform when the trail-
ing-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 while sub-
stantially 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 mate-
rial between said peripheral edges, 
wherein said structures elastically deform when the trail-
ing-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.
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