

COMPOSITE STRUCTURES FOR AERODYNAMIC COMPONENTS

TECHNOLOGICAL FIELD

The presently disclosed subject matter relates to composite structures, in particular for aerodynamic components or for use with aerodynamic components.

BACKGROUND

It is known to manufacture wings and similar aerodynamic components from non-metallic composite materials. In some cases, the mechanical structure of the composite wing includes a torsion box having two axially spaced spars interconnected via two spaced skins, the two spars being spaced aft from the leading edge of the aerodynamic component.

It is also known to carry external stores on wings made from composite materials. Conventionally, pylon-type structures are used for such purposes, having similar design features as in metallic wings. Such pylons are conventionally mounted to the underside of the composite material wings and in load-bearing contact with the composite wing main spar, which conventionally carries the majority weight of the loads from the external stores.

GENERAL DESCRIPTION

According to a first aspect of the presently disclosed subject matter there is provided a composite structure for an aerodynamic component having an aerofoil-like cross-section (also referred to herein as an “aerofoil”) and a leading edge, the composite structure being in the form of a torsion box arrangement having a core, the torsion box arrangement being made from composite materials, wherein the torsion box has a forward wall, an aft wall, a top wall and a bottom wall, together defining said core, and wherein said front wall is formed as the leading edge of the aerodynamic component.

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Thus, according to this aspect of the presently disclosed subject matter there is provided a composite structure for an aerodynamic component having an aerofoil-like cross-section and a leading edge, the composite structure being in the form of a torsion box arrangement made from composite materials and having a core, the torsion box having a forward wall, an aft wall, a top wall and a bottom wall, together defining the core, the front wall being formed as the leading edge of the aerodynamic component.

In other words the front wall does not have the shape of a spar or of the web of a spar, i.e., the front wall is non-planar and does not have a flat shape, but is rather in a shape of a “C” following the contour of the leading edge of the aerodynamic component.

By leading edge is meant the actual leading edge of the aerodynamic component in examples where the leading edge is fixed with respect to the aerofoil, or, in aerofoils in which include a movable slat leading edge is meant the leading edge of the aerodynamic component excluding the slat.

For example, said top wall is formed with an external first surface corresponding to a suction surface of the aerodynamic component, and wherein said bottom wall is formed with an external second surface corresponding to a pressure surface of the aerodynamic component. Optionally for example:

said forward wall is longitudinally spaced from said aft wall by a longitudinal spacing; and/or

said upper wall is transversely spaced from said bottom wall by a transverse spacing; and/or

the forward wall is connected to a respective first edge of each one of said top wall and said bottom wall; and/or

the aft wall is connected to a respective second edge of each one of said top wall and said bottom wall; and/or

said forward wall and said aft wall have a transverse dimension whereby to provide said transverse spacing; and/or

said top wall and said bottom wall have a longitudinal dimension whereby to provide said longitudinal spacing.

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Additionally or alternatively, for example, said forward wall comprises an externally facing aerodynamic leading edge surface and an internally facing leading end inner surface.

Additionally or alternatively, for example:

said top wall comprises an externally facing first aerodynamic surface and an internally facing first inner surface;

said bottom wall comprises an externally facing second aerodynamic surface and an internally facing second inner surface;

Additionally or alternatively, for example, said aft wall is configured structurally as a trailing end spar and includes an externally facing trailing end surface and an internally facing leading end inner surface. For example:

said forward wall, said aft wall, said top wall, and said bottom wall are made from composite materials; and

wherein said internally facing leading end inner surface, said internally facing first inner surface, said internally facing second inner surface, and said internally facing leading end inner surface enclose said core.

Additionally or alternatively, for example, said torsion box arrangement extends laterally between a first torsion box end and a second torsion box end. For example, said torsion box arrangement has a lateral dimension between a first torsion box end and a second torsion box end.

Additionally or alternatively, for example, said torsion box arrangement has an absence of any structural member, different from said aft wall, transversely spanning said hollow core between said top wall and said bottom wall.

Additionally or alternatively, for example, said core is spar-less.

Additionally or alternatively, for example, said torsion box arrangement has an absence of any structural member, different from said aft wall, accommodated in said core and extending in a spanwise direction.

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Additionally or alternatively, for example, the torsion box arrangement, has an absence of a main spar, or of a web of such a main spar, at the respective conventional location of such a main spar in conventional wings.

Additionally or alternatively, for example, the torsion box arrangement, has an absence of a main spar, or of a web of such a main spar, at least between the aerofoil leading edge and 60% of a chord of the aerofoil, or at least between the aerofoil leading edge and 50% of the chord of the aerofoil, or at least between the aerofoil leading edge and 40% of the chord of the aerofoil, or at least between the aerofoil leading edge and 30% of the chord of the aerofoil, or at least between 20% and 30% of the chord of the aerofoil aft of the aerofoil leading edge.

Additionally or alternatively, for example, said core is rib-less.

Additionally or alternatively, for example, said torsion box arrangement has an absence of any rib structural member, accommodated in said core between said top wall and said bottom wall.

Additionally or alternatively, for example, said top wall and said bottom wall each extends aft in a chordwise direction at least past a chordwise location of the neutral point NP of the aerofoil.

Additionally or alternatively, for example, said top wall and said bottom wall each extends aft in a chordwise direction at least past between 20% and 30% of a chord of the aerofoil. For example, said top wall and said bottom wall each extends aft in a chordwise direction more than 40%, or more than 50% or more than 60% or more than 70% of the chord.

Additionally or alternatively, for example, said forward wall is configured structurally as a leading end spar.

Additionally or alternatively, for example, said forward wall, said aft wall, said top wall, and said bottom wall are made exclusively from a first composite material.

Additionally or alternatively, for example, said forward wall, said aft wall, said top wall, and said bottom wall are made from a first composite material comprising

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multiple layers of composite fibers embedded in a matrix, and further comprising a second composite material comprising a stiffening structure.

Additionally or alternatively, for example, wherein said forward wall, said aft wall, said top wall, and said bottom wall have an absence of metallic materials.

Additionally or alternatively, for example, said torsion box arrangement has a closed transverse section.

Additionally or alternatively, for example, said core is a hollow core.

Additionally or alternatively, for example, said core is at least partially fillable with a liquid material.

Additionally or alternatively, for example, said top wall comprises at least one first stiffening member co-extensive therewith (along a direction parallel to the span axis of the aerodynamic member) and joined thereto. For example, said at least one first stiffening member is made from third composite materials comprising a unidirectional fiber structure embedded in a matrix.

Additionally or alternatively, for example, said bottom wall comprises at least one second stiffening member co-extensive therewith (along a direction parallel to the span axis of the aerodynamic member) and joined thereto. For example, said at least one second stiffening member is made from fourth composite materials comprising a unidirectional fiber structure embedded in a matrix.

Additionally or alternatively, for example, said externally facing aerodynamic leading edge surface, said first externally facing first aerodynamic surface, said externally facing second aerodynamic surface and said externally facing trailing end surface define an outer mold line.

Additionally or alternatively, for example, said internally facing leading end inner surface, said internally facing first inner surface, said internally facing second inner surface, and said internally facing leading end inner surface define an inner mold line.

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Additionally or alternatively, for example, the aerodynamic component is a wing, and wherein said forward wall is configured aerodynamically as a leading edge of the wing

Additionally or alternatively, for example, the aerodynamic component is any one of: a vertical stabilizer, horizontal stabilizer, vane, canard, rudder, other aerodynamic control surfaces.

Additionally or alternatively, for example, the composite structure according to the aspect of the presently disclosed subject matter further comprises a load-bearing composite structure for use with the aerodynamic component, according to a second aspect of the presently disclosed subject matter. For example, the aerodynamic component has an external aerodynamic surface including said leading edge and a trailing edge, said suction surface extending between the leading edge and the trailing edge, and said pressure surface extending between the leading edge and the trailing edge, the load bearing composite structure being made from composite materials and configured for being joined to the external aerodynamic surface such as to be in overlying abutting relationship with at least a contact surface portion of the external aerodynamic surface, the contact surface portion including the leading edge, at least a forward portion of the suction surface and at least a forward portion of the pressure surface of the external aerodynamic surface, the load-bearing composite structure being further configured for supporting at least one external load.

For example, the load-bearing composite structure comprises a wing-coupling portion configured for coupling to the aerodynamic component, and an external load coupling portion configured for coupling to said at least one external load. For example, said wing-coupling portion is configured for being joined or otherwise connected to the external aerodynamic surface such as to be in overlying abutting and load bearing relationship with at least said contact surface portion.

Additionally or alternatively, for example, said wing-coupling portion comprises a functional surface conforming to the contact surface portion of the external aerodynamic surface.

Additionally or alternatively, for example, said external load coupling portion comprises a pair of spaced lateral walls for holding therein at least a part of said at least one

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external load, and further comprising at least one peg configured for concurrently traversing said pair of spaced lateral walls and said part of said at least one external load.

Additionally or alternatively, for example, said external load is in the form of any one of:

- a boom connected to an empennage;
- an external store having a pylon structure;
- an external store having a pylon structure, wherein said external stores includes any one of: engine, a fuel tank, a camera, weapons.

According to the second aspect of the presently disclosed subject matter there is provided a load-bearing composite structure for use with an aerodynamic component, the aerodynamic component having an external aerodynamic surface including a leading edge and a trailing edge, a suction surface extending between the leading edge and the trailing edge, and a pressure surface extending between the leading edge and the trailing edge, the composite structure being made from composite materials and configured for being joined to the external aerodynamic surface such as to be in overlying abutting relationship with at least a contact surface portion of the external aerodynamic surface, the contact surface portion including the leading edge, at least a forward portion of the suction surface and at least a forward portion of the pressure surface of the external aerodynamic surface, the load-bearing composite structure being further configured for supporting at least one external load.

Thus according to this aspect of the presently disclosed subject matter there is provided a load-bearing composite structure for use with an aerodynamic component and configured for supporting at least one external load, this composite structure being made from composite materials and configured for being joined to the external aerodynamic surface of the aerodynamic component such as to be in overlying abutting relationship with at least a contact surface portion of the external aerodynamic surface, including the leading edge, at least a forward portion of each of the suction surface and the pressure surface thereof.

For example, the load-bearing composite structure comprises a wing-coupling portion configured for coupling to the aerodynamic component, and an external load

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coupling portion configured for coupling to said at least one external load. For example, said wing-coupling portion is configured for being joined or otherwise connected to the external aerodynamic surface such as to be in overlying abutting and load bearing relationship with at least said contact surface portion.

Additionally or alternatively, for example, said wing-coupling portion comprises a functional surface conforming to the contact surface portion of the external aerodynamic surface.

Additionally or alternatively, for example, said external load coupling portion comprises a pair of spaced lateral walls for holding therein at least a part of said at least one external load. For example, the load-bearing composite structure comprises at least one peg configured for concurrently traversing said pair of spaced lateral walls and said part of said at least one external load.

Additionally or alternatively, for example, said external load is in the form of a boom connected to an empennage.

Additionally or alternatively, for example, said external load is in the form of an external store having a pylon structure. For example, said external stores includes any one of: engine, a fuel tank, a camera, weapons.

Additionally or alternatively, for example, the aerodynamic component is a wing.

A feature of at least one example according to the first aspect of the presently disclosed subject matter is that there is provided a composite structure for an aerodynamic component having an aerofoil-like cross-section, which can be lighter in weight and/or less expensive to manufacture, than a similar composite structure made in a conventional manner having a main spar.

Another feature of at least one example according to the first aspect of the presently disclosed subject matter is that there is provided a composite structure for an aerodynamic component having an aerofoil-like cross-section, which requires less component parts for the manufacture thereof, than a similar composite structure made in a conventional manner having a main spar.

Another feature of at least one example according to the first aspect of the presently disclosed subject matter is that there is provided a composite structure for an aerodynamic component having an aerofoil-like cross-section, and which can be used as a so-called “wet wing” for fuel storage, wherein there is additional volume available for fuel storage as compared to a similar conventional wing in which such fuel storage is typically between the front and rear spars of the conventional torsion box of the wing.

A feature of at least one example according to the second aspect of the presently disclosed subject matter is that a so-called external rib is provided that replaces the need for as conventional pylon, allowing the addition of payload at any span-wise location on the wing, even after the wing manufactured.

Another feature of at least one example according to the second aspect of the presently disclosed subject matter is that a so-called external rib is provided can be removed from the wing when not in use or when desired, since the wing is designed structurally in the absence of such an external rib.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand the subject matter that is disclosed herein and to exemplify how it may be carried out in practice, examples will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 is a side view of a first example of a composite structure for an aerodynamic component, according to a first aspect of the presently disclosed subject matter.

Fig. 2 is a plan view of the example of Fig 1.

Fig. 3 is a transverse cross-section of the example of Fig. 1, schematically illustrating an example of the manufacturing construction thereof.

Fig. 4 is a cross-sectional and partially cut-out side view of a first example of a composite structure for an aerodynamic component, according to a second aspect of the presently disclosed subject matter; **Fig. 4(a)** is a cross-sectional view of the example of Fig. 4 taken along section A-A; **Fig. 4(b)** is a cross-sectional view of the example of Fig.

4 taken along section B-B; **Fig. 4(c)** is a cross-sectional view of the example of Fig. 4 taken along section C-C.

Fig.5 is a cross-sectional and partially cut-out side view of an alternative variation of the first example of Figs. 4, 4(a), 4(b), 4(c); **Fig. 5(a)** is a cross-sectional view of the example of Fig. 5 taken along section A-A; **Fig. 5(b)** is a cross-sectional view of the example of Fig. 5 taken along section B-B; **Fig. 5(c)** is a cross-sectional view of the example of Fig. 5 taken along section C-C.

Fig.6 is a cross-sectional side view of another alternative variation of the first example of Figs. 4, 4(a), 4(b), 4(c); **Fig. 6(a)** is a cross-sectional view of the example of Fig. 6 taken along section A-A; **Fig. 6(b)** is a cross-sectional view of the example of Fig. 6 taken along section B-B.

DETAILED DESCRIPTION

Referring to Figs. 1 and 2, a composite structure according to a first example of a first aspect of the presently disclosed subject matter, generally designated **100**, is in the form of a load-bearing external skin **300** having an outer skin surface **390**, and is provided for an aerodynamic component **200**. In other words, the aerodynamic component **200** has a structure corresponding to the composite structure **100**.

The aerodynamic component **200** is configured for aerodynamically interacting with an airflow and has an aerofoil-like cross section. By “aerofoil-like cross-section” is meant that the aerodynamic component **200** has a cross-section shaped as at least the front end of an aerofoil section **AS**, having at least an external aerodynamic surface **205** including an externally facing aerofoil leading edge **210**, an externally facing first aerodynamic surface **220**, an externally facing second aerodynamic surface **230** generally co-extensive with and spaced from the first aerodynamic surface **220**, and a trailing end surface **240**. In at least this example, the aerofoil leading edge **210** has a leading edge radius, having a non-zero dimension.

In the illustrated example, the aerodynamic component **200** is at least a part of a subsonic or transonic wing **10**, for generating aerodynamic lift for an aircraft, in which in at

least some examples the wing can be connected to an aircraft fuselage. The wing has a span axis **SA** generally orthogonal to the aerofoil-like cross sections. However, in variations of this example and in other examples, the aerodynamic component **200** can instead be any one of: vane, rudder, aileron, flap, horizontal stabilizer, canard, and so on.

Thus, in the illustrated example, the first aerodynamic surface **220** corresponds to a suction surface of the aerofoil and extends aft from the aerofoil leading edge **210**, and the second aerodynamic surface **230** corresponds to a pressure surface of the aerofoil and also extends aft from the aerofoil leading edge **210**. The first aerodynamic surface **220** is transversely spaced from the second aerodynamic surface **230** by the thickness of the aerofoil, which can vary along the chord of the aerofoil.

In this example, the trailing end surface **240** is joined to an aft fairing **260** configured for being in spaced relationship with respect to an actuable control surface **290**, for example an aileron or flap, via gap **295**. In alternative variations of this examples, and in other examples, the aft fairing **260** is instead configured as a trailing edge of the wing, and thus the cross-section of the aerodynamic component **200** includes the corresponding full aerofoil including the trailing edge of the aerofoil.

According to the first aspect of the presently disclosed subject matter, the composite structure **100** has a monocoque construction, in which the external skin **300** carries all or a major part of the stresses of the wing **10**. In particular, the composite structure **100** is in the form of a torsion box arrangement **310** having a core **HC**, which in this example is a hollow core that optionally can be partially filled or fully filled with liquid fuel. In other words, the external skin **300** has a form corresponding to the aforesaid torsion box arrangement **310** to provide the monocoque construction.

By “torsion box arrangement” is meant having a general arrangement of a torsion box, having a general construction including layers (or skins) surrounding a core (which for example can be a hollow core that stays hollow, or for example for example can be an initially hollow core that can be reversibly filled - partially or fully - with a material, for example liquid fuel) in a closed polygonal manner around the core, and designed to resist torsion under an applied load, typically aerodynamic loads, and the torsion box structure typically uses the properties of the relatively thin skins to carry the loads.

The composite structure **100**, in particular the torsion box arrangement **310**, and more in particular the skin **300** comprises a leading end wall **330** (also referred to interchangeably herein as a forward wall), a trailing end wall **350** (also referred to interchangeably herein as an aft wall), a first outer wall **320** (also referred to interchangeably herein as a top wall), and a second outer wall **340** (also referred to interchangeably herein as a bottom wall).

The leading end wall **330** is longitudinally spaced from the trailing end wall **350** by a longitudinal spacing **LS**.

The first outer wall **320** is transversely spaced from the second outer wall **340** by a transverse spacing **TS**.

The leading end wall **330** is connected or otherwise joined to a first end **325** of the first outer wall **320** and to a first end **345** of the second outer wall **340**.

The trailing end wall **350** is connected or otherwise joined to a second end **327** of the first outer wall **320** and to a second end **347** of the second outer wall **340**.

The leading end wall **330** and said trailing end wall **350** have respective transverse dimensions **TD_L** and **TD_T** whereby to provide the transverse spacing **TS**; the first outer wall **320** and the second outer wall **340** have respective longitudinal dimensions **LD₁** and **LD₂** whereby to provide the longitudinal spacing **LS**.

It is to be noted that both the externally facing first aerodynamic surface **220**, and the externally facing second aerodynamic surface **230** (and thus top wall **320** and bottom wall **340**) extend aft in a chordwise direction at least well past the chordwise location of the neutral point **NP** of the aerofoil, which is typically between 20% and 30% of the chord. For example, both the externally facing first aerodynamic surface **220**, and the externally facing second aerodynamic surface **230** extend aft in a chordwise direction to (and thus the trailing end surface **240** is located at) more than 40%, or more than 50% or more than 60% or more than 70% of the chord.

The leading end wall **330** is configured aerodynamically as an aerofoil leading edge, comprising or defining the externally facing aerodynamic leading edge surface **210**, and further comprises an internally facing leading end inner surface **212**. It is to be noted that at

least in this example, the leading end wall **330** is generally C-shaped in cross-section, corresponding to the leading edge of the aerofoil type cross-section of the wing **10**, and that the internally facing first inner surface **212** is also generally C-shaped in cross-section.

The first outer wall **320** comprises or defines the externally facing first aerodynamic surface **220**, and further comprises an internally facing first inner surface **222**.

The second outer wall **340** comprises or defines the externally facing second aerodynamic surface **230**, and further comprises an internally facing second inner surface **232**.

The trailing end wall **350** is configured structurally as a trailing end spar and includes or defines the externally facing trailing end surface **240**, and further comprises an internally facing leading end inner surface **242**. According to the first aspect of the presently disclosed subject matter the trailing end wall **350** does not resist any or even a majority of the bending loads of the wing **10**, and can be considered to act essentially as a continuation of the load-bearing external skin **300** to geometrically “close” the aft end of the torsion box arrangement **310**.

The skin **300**, and thus the torsion box arrangement **310**, comprises the leading end wall **330**, the trailing end wall **350**, the first outer wall **320**, and the second outer wall **340**, joined or connected serially to one another to form a closed body in planes normal to the span direction **SD** of the wing **10**.

According to the aforesaid first aspect of the presently disclosed subject matter, the skin **300**, and in particular the leading end wall **330**, the trailing end wall **350**, the first outer wall **320**, and the second outer wall **340**, are made from composite materials, in particular non-metallic materials, as will become clearer herein.

Furthermore, according to aforesaid first aspect of the presently disclosed subject matter, the skin **300** encloses the hollow core **HC**, which at least in some examples can be used as an internal fuel tank or a wing fuel tank for containing liquid fuel. In particular, the internally facing leading end inner surface **212**, the internally facing first inner surface **222**, the internally facing second inner surface **232**, and the internally facing trailing end inner surface **242** enclose, face and define the hollow core **HC**.

It is to be noted that the internally facing leading end inner surface **212**, the internally facing first inner surface **222**, the internally facing second inner surface **232**, and the internally facing trailing end inner surface **242** are contiguous to thereby define a skin inner surface **380**.

Inner skin surface **380** thus defines and fully encloses the hollow core **HC**.

According to the aforesaid first aspect of the presently disclosed subject matter, the torsion box arrangement **310** extends laterally, i.e. along span axis **SA**, between a first torsion box end **312** and a second torsion box end **314**. For example the first torsion box end **312** can be close to or include the wing tip of wing **10**, and/or the second torsion box end **314** can be close to or include the wing root of the wing **10**. Thus, torsion box arrangement **310** has a lateral dimension between a first torsion box end **312** and a second torsion box end **314**, corresponding to the full span **S** or to part of the span **S** of the wing **10**.

It is to be noted that, according to the aforesaid first aspect of the presently disclosed subject matter, the composite structure **100**, in particular the torsion box arrangement **310**, and more in particular the skin **300**, has an absence of any structural member, different from trailing end wall **350**, transversely spanning said hollow core **HC** between the first outer wall **320** and the second outer wall **340**, or otherwise accommodated in the hollow core and extending in a spanwise direction, i.e., along the span axis **SA**. For example, the hollow core **HC** is spar-less, i.e., there are no spars within the hollow core **HC**. In particular, the composite structure **100**, in particular the torsion box arrangement **310**, and more in particular the skin **300**, has an absence of a main spar, or of a web of such a main spar, at the respective conventional location of such a main spar in conventional wings, i.e., at least between the aerofoil leading edge **210** and 60% of the chord of the aerofoil, more particularly at least between the aerofoil leading edge **210** and 50% of the chord of the aerofoil, more particularly at least between the aerofoil leading edge **210** and 40% of the chord of the aerofoil, more particularly at least between the aerofoil leading edge **210** and 30% of the chord of the aerofoil, more particularly at least between 20% and 30% of the chord of the aerofoil aft of the aerofoil leading edge **210**.

Similarly, according to the aforesaid first aspect of the presently disclosed subject matter, the hollow core **HC** is rib-less, i.e., there are no internal ribs within the hollow core **HC**, and thus the torsion box arrangement has an absence of any rib structural member,

accommodated within the hollow core **HC** between the first outer wall **320** and the second outer wall **340**.

Referring also to Fig. 3, the torsion box arrangement **310** of this example can be provided in two parts that are manufactured separately and then joined together, for example comprising a first body part **315** and a second body part **317**.

In the example, of Fig. 3, the first body part **315** includes the leading end wall **330**, second outer wall **340**, trailing end wall **350**, and a forward part of the first outer wall **320**. The second body part **317** includes the aft part of the first outer wall **320**, and is affixed to the first body part **315** to form the closed monocoque construction of the torsion box arrangement **310**. It is to be noted that optionally, and in the illustrated example of Fig. 3, the second body part **317** also includes an aft-projecting wall corresponding to an upper fairing portion **262** of fairing **260**, and a lower fairing portion **264** of fairing **260** can be connected to the upper fairing portion **262** and to an aft portion of the main body part **315**.

In the illustrated example of Figs. 1 to 3, the composite structure **100**, in particular the torsion box arrangement **310**, further comprises a first stiffening member **382** and a second stiffening member **384**, both running nominally parallel to the span axis **SA**. In at least this example the first stiffening member **382** is affixed to or embedded in the first outer wall **320**, and the second stiffening member **384** is affixed to or embedded in the second outer wall **340**. The first stiffening member **382**, and the second stiffening member **384** are configured for providing further stiffness to the composite structure **100** in a direction nominally parallel to the span axis **SA**.

In at least this example the first stiffening member **382** and the second stiffening member **384** are located at the same chordwise location, and thus can be considered to be similar in function to the flanges of a web-less fictitious I-beam.

For example, the first stiffening member **382** and the second stiffening member **384** are each located chordwise direction at or in the vicinity of the neutral point **NP** of the aerofoil. for example, the first stiffening member **382** and the second stiffening member **384** are each located chordwise direction at least between the aerofoil leading edge **210** and 60% of the chord of the aerofoil, more particularly at least between the aerofoil leading edge **210** and 50% of the chord of the aerofoil, more particularly at least between the aerofoil leading

edge **210** and 40% of the chord of the aerofoil, more particularly at least between the aerofoil leading edge **210** and 30% of the chord of the aerofoil, more particularly at least between 20% and 30% of the chord of the aerofoil aft of the aerofoil leading edge **210**.

Furthermore, for example, the first stiffening member **382** and the second stiffening member **384** each have a polygonal cross-section, for example a quadrilateral cross-section, for example a rectangular cross-section. However in alternative variations of this example and in other examples, first stiffening member **382** and the second stiffening member **384** are located at different chordwise locations – for example the first stiffening member **382** can be forward of the second stiffening member **384**, or, the first stiffening member **382** can be aft of the second stiffening member **384**.

In at least this example the first stiffening member **382** is made from a suitable first composite, and non-metallic, material, and the second stiffening member **384** is made from a suitable second composite, and non-metallic, material, as will become clearer herein. While in at least this example, the first composite material and the second composite material are the same material, in alternative variations of this example, the first composite material and the second composite material are different materials one to the other.

In at least this example, for example, the first stiffening member **382** and the second stiffening member **384** are each made from anisotropic composite materials. For example, the first stiffening member **382** and/or the second stiffening member **384** can include a plurality of layers **P8**, **P9**, respectively, overlaid over one another. For example, each one of layer **P8** and layer **P9** can include a plurality, for example four overlaid plies, in which each ply comprises a respective plurality of unidirectional fibers embedded in a matrix, the unidirectional fibers being in general parallel relationship to the span axis **SA**.

Referring also to Fig. 3, the illustrated example of the torsion box arrangement **310**, in particular each one of the first body part **315** and the second part **317**, comprises a multi-layered structure, in particular a sandwich structure, having one or more outer layers on either side of a lightweight core.

For example, the main body part **315** comprises an innermost layer **P4** that defines a corresponding part of the skin inner surface **380**. One or more additional inner intermediate layers **P3** are overlaid over innermost layer **P4**. A first core layer **CL1** is overlaid over layer

P3, and the first stiffening member **382** and the second stiffening member **384** are also overlaid over layer **P3** at locations in which the thickener layer is modified to accommodate the stiffening members. One or more outer intermediate layers **P2** are overlaid over the first core layer **CL1**, and a final uppermost layer **P1** is overlaid over the layer **P2**.

The second body part **317** can be made from a plurality of layers **P5** overlaid over one another. The second body part **317** can also be made integrally or joined with a first aft portion **318** corresponding to the upper fairing portion **262** of fairing **260**.

The first aft portion **318** can include a plurality of layers **P6** overlaid over one another, and overlying a second core layer **CL2**.

The body part **315** can also be made integrally or joined with a second aft portion **319** corresponding to the lower fairing portion **264** of fairing **260**.

The second aft portion **319** can include a plurality of layers **P7** overlaid over one another, and overlying a third core layer **CL3**.

Once formed, the first body part **315** can be joined to the second body part **317**, for example via any suitable adhesive. Furthermore, the second aft portion **319** can be joined to the first aft portion **318** to form fairing **260**.

Each of the layers **P1, P2, P3, P4, P5, P6, P7** can be similar to one another or different from one another.

In at least this example, each of the layers **P1, P2, P3, P4, P5, P6** is bidirectional or isotropic.

For example, each one of the layers **P1, P2, P3, P4** comprises a respective first plurality of first fibers and a second plurality of second fibers embedded in a matrix, the second fibers being in a non-parallel orientation (in this example, in orthogonal orientation) with respect to the first fibers. In this example, the first fibers are oriented at +45° to the span direction **SA**, and the second fibers are oriented at -45° to the span direction **SA**. In alternative variations of this example, the first fibers are oriented at +40° to the span direction **SA**, and the second fibers are oriented at -50° to the span direction **SA**. In other alternative variations of this example, the first fibers are oriented at +30° to the span direction **SA**, and the second fibers are oriented at -60° to the span direction **SA**.

For example, layer **P5** can include a plurality, for example four overlaid plies, in which each ply comprises a respective third plurality of third fibers and a fourth plurality of fourth fibers embedded in a matrix, the fourth fibers being in a non-parallel orientation (in this example, in orthogonal orientation) with respect to the third fibers.

For example, one of layer **P6** or layer **P7** can include a plurality, for example two overlaid plies, in which each ply comprises a respective fifth plurality of fifth fibers and a sixth plurality of sixth fibers embedded in a matrix, the sixth fibers being in a non-parallel orientation (in this example, in orthogonal orientation) with respect to the fifth fibers.

For example, each such matrix referred to above can be a curable material, and can be or can include one or more of the following, for example: epoxy resin, or any other suitable resinous matrix, thermoplastic resin or other thermosetting resin, or polyester resins, or vinyl ester resins, or phenolic resins, or polyimides, or polybenzimidazoles (PBI), or bismaleimides (BMI), or semicrystalline thermoplastics, or amorphous thermoplastics, or polyether ether ketones.

For example, the respective first fibers and/or the respective second fibers and/or the respective third fibers and/or the respective fourth fibers and/or the respective fifth fibers and/or the respective sixth fibers and/or unidirectional fibers can be or can include one or more of the following fibers: carbon/graphite fibers, or fiberglass fibers, or Kevlar fibers, or boron fibers, or ceramic fibers.

For example, the first core layer **CL1** and/or the second core layer **CL2** and/or the third core layer **CL3** can be in the form of a honeycomb construction, for example anisotropic honeycomb construction.

For example, each such honeycomb construction can be made from or can include one or more of the following materials, for example: aramid paper, fiberglass, Kraft paper, thermoplastics, aluminium, steel, titanium, carbon, ceramics.

For example, each such honeycomb construction can have a regular hexagonal honeycomb structure, or a flexicore structure, or a bisected honeycomb structure, or an overexpanded structure.

Alternatively, the first core layer **CL1** and/or the second core layer **CL2** and/or the third core layer **CL3** can be in the form of a foam construction, and can be made from or can include one or more of the following materials, for example: polystyrene (Styrofoam), phenolic, polyurethane, polypropylene, polyvinyl chloride (PVC), polymethacrylimide (Rohacell).

Alternatively, the first core layer **CL1** and/or the second core layer **CL2** and/or the third core layer **CL3** can be made from balsa wood.

For example, the overlaying process of the layers can be carried out with a mandrel or in a mold, as is known in the art.

It is to be noted that at least in the illustrated example of the torsion box arrangement **310**, in particular each one of the first body part **315** and the second part **317**, such a torsion box arrangement **310** is provided having sufficient mechanical properties to meet, in conjunction with the first stiffening member **382** and the second stiffening member **384**, the design bending moment requirement for the aerodynamic component **200**. For example, the stiffness and/or thickness of the skin corresponding to the torsion box arrangement **310**, in particular each one of the first body part **315** and the second part **317**, is greater than would otherwise be if the torsion box arrangement **310** were to include a main spar in the conventional manner. Parameters that can be adjusted to provide such mechanical properties can for example include one or more of the following: sizing of aerofoil, the skin thickness, the profiling, expected bending loads, the locations of the first stiffening member **382** and the second stiffening member **384**. Such parameters can be chosen to avoid risk of skin buckling for the torsion box arrangement **310** at the design bending moment and/or at other desired conditions.

Without being bound to theory, the inventors consider that the torsion box construction according to the first aspect of the presently disclosed subject matter, in which the forward wall of the torsion box is formed as the aerodynamic leading edge of the aerodynamic component (i.e., in the shape of the aforesaid aerodynamic leading edge, and not as a relatively flat wall) and optionally includes part of the first outer wall and/or part of the second outer wall of the aerodynamic component, provides the necessary stiffness to the wing **10**, without the need for and thus excluding a forward main spar, or ribs. In at least some examples this is accomplished by providing the first stiffening member **382** and the

second stiffening member **384** in place of the flanges of a conventional main spar, in which the first stiffening member **382** and the second stiffening member **384** are made from composite (non-metallic) materials having unidirectional fibers running along the span direction **SA**, and in which the function of web of such a conventional main spar is instead accomplished by the skin of the torsion box arrangement **310**.

Referring to Fig. 4, 4(a), 4(b), 4(c) a composite structure according to a first example of a second aspect of the presently disclosed subject matter, generally designated **400**, is in the form of a load-bearing composite structure, and is provided for use with an aerodynamic component **200**.

In at least some examples, the load-bearing composite structure **400** can be considered as an external “rib” for the aerodynamic component, and further configured for enabling an external load **EL** to be supported on the wing via the load-bearing composite structure **400**. Thus, the terms “external rib”, and “external rib structure” are used herein interchangeably with the load-bearing composite structure according to the second aspect of the presently disclosed subject matter.

As with the first aspect of the presently disclosed subject matter, *mutatis mutandis*, the aerodynamic component **200** is configured for aerodynamically interacting with an airflow and has an aerofoil-like cross section, and is at least a part of a subsonic or transonic wing **10**, for generating aerodynamic lift for an aircraft, in which in at least some examples the wing can be connected to an aircraft fuselage. The wing has a span axis **SA** generally orthogonal to the aerofoil-like cross sections.

In this example, and as disclosed above, the aerodynamic component **200** has an external aerodynamic surface **205** including a leading edge **210** and a trailing edge, a suction surface **220** extending between the leading edge and the trailing edge, and a pressure surface **230** extending between the leading edge **210** and the trailing edge. The suction surface **220** is transversely spaced from the pressure surface **230** by the thickness of the aerofoil, which can vary along the chord of the aerofoil.

According to the second aspect of the presently disclosed subject matter, while the aerodynamic component is typically made from composite (and non-metallic) materials, the specific mechanical structure can be for example as disclosed above with reference to the

first aspect of the presently disclosed subject matter, or, alternatively, the mechanical structure for the aerodynamic component can be different thereof, for example including conventional composite structure for the aerodynamic component, as are well known in the art.

According to the second aspect of the presently disclosed subject matter, the composite structure **400** is made from composite (i.e., non-metallic) materials and comprises a wing-coupling portion **410** configured for coupling to an aerodynamic component **200** in the form of a wing **10**, and an external load coupling portion **450** configured for coupling to an external load **EL**.

The composite structure **400**, in particular wing-coupling portion **410**, is configured for being joined or otherwise connected to the external aerodynamic surface **205** of the wing **10** such as to be in overlying abutting and load bearing relationship with at least a contact surface portion **CP** of the external aerodynamic surface **205**. Furthermore, the contact surface portion **CP** includes (referring to the transverse cross-section of the wing) the leading edge **210**, at least a forward portion **225** of the suction surface **220** and at least a forward portion **235** of the pressure surface **230** of the external aerodynamic surface **205**; furthermore, the load-bearing composite structure **400** is further configured for supporting at least one external load **EL**.

The load-bearing composite structure **400**, in particular wing-coupling portion **410**, in at least this example is in the form of a generally C-shaped body **420** (in side view) having a functional surface **430** conforming to the contact surface portion **CP** of the external aerodynamic surface **205**.

In at least some examples, the load-bearing composite structure **400** is fixed to the wing **10** via connection of the functional surface **430** of the wing-coupling portion **410**, with the contact surface portion **CP** of the external aerodynamic surface **205**. Such connection can be integral, wherein the load-bearing structure **400** is manufactured together with the wing as a single integral unit, or, alternatively, the load-bearing composite structure **400** and the wing **10** are manufactured separately, and then the load-bearing composite structure **400** is affixed to the wing **10**, for example co-bonded with carbon/epoxy fabric splice on the outer wing surface of the aerodynamic component **200**.

In at least this example, and as best seen in Fig. 4(a), the load-bearing composite structure **400**, in particular the C-shaped body **420** of wing-coupling portion **410**, has a hollow structure, in which the outer skin **425** of C-shaped body **420** encloses a space **422**. The outer skin **425** also has a U-shaped cross-section (in plan view) at least at or near the leading edge **210**, having a base **426** of the “U” and arms **427** of the “U”.

In at least this example, the base **426** of the “U” is rounded or otherwise aerodynamically contoured, for example as a leading edge of an airfoil, to minimize drag.

In at least this example, the upper part of the C-shaped body **420** extends over the suction surface **220** aft as far as the contact portion **CP**, and over the pressure surface **230** up to the trailing end thereof. In particular, the arms **427** extend over the pressure surface **230** up to the trailing end thereof.

In at least this example, the external-load coupling portion **450** extends downwardly from the wing-coupling portion **410**, and comprises a forward end **455** defining a concave recess **456**, and side walls **460** extending aft, co-extensive with the arms **427**.

The side walls **460** are spaced by spacing **TC** (Fig. 4(b)), and have a forward portion **460A**, in which (for example to save weight) the height dimension *h* diminishes from a maximum height at recess **456**, to a minimum at a point **P**, and an aft portion **460B**, in which the height dimension increases from a minimum at a point **P** to a maximum height at or close to the aft end **460C** of the walls **460**.

In this example, the composite structure **400** is made from composite (i.e., non-metallic) materials. In particular, in this example the wing-coupling portion **410** is in the form of a structural fairing made of carbon/epoxy fabric layers for example up to 2mm thickness, and having quasi isotropic properties.

Furthermore, in this example the external load coupling portion **450** is in the form of a structural fairing made of carbon/epoxy fabric layers for example up to 2mm thickness, and having quasi isotropic properties

In this example, the external load **EL** is in the form of a boom **500** having a forward end **510** that is configured for being received in concave recess **456**, and extends aft, enclosed laterally between the side walls **460**, and further extending aft away from the side

walls **460**. In operation, the boom **500** carries loads from the empennage (not shown) to the wing in the form of aerodynamic component **200**.

The boom **500** can be affixed or otherwise secured in load bearing relationship with respect to the composite structure **400**, in particular with respect to the external load coupling portion **450**, in any suitable manner, reversibly or non-reversibly. In this example, a first peg **520** is inserted into the end **510** via the forward end **455** and concave recess **456**, providing a friction fit therebetween. A second peg **530** is inserted into an aft portion **540** of the boom **500** via the side walls **460**, in particular the respective aft portions **460B** thereof, providing a friction fit therebetween.

It is to be noted that the composite structure **400** is not part of the aerodynamic structure **200** per se, and thus the aerodynamic structure **200** for example in the form of a wing, is designed structurally to meet the loading requirements of thereof even in the absence of the composite structure **400**. Furthermore, the composite structure **400** does not require conventional “hard points” on the wing, and thus does not require the wing to have internal spars or ribs. Thus, according to the second aspect of the presently disclosed subject matter the composite structure **400** can optionally be removed when there is no requirement for this, without adversely affecting the structural integrity of the aerodynamic structure **200** per se.

In an alternative variation of the example of Figs. 4, 4(a), 4(b), and 4(c), and referring to Figs. 5, 5(a), 5(b), 5(c), the aft walls **460** are formed with a uniform height, and further include a bottom wall **470** joined to the bottom edges of the side walls **460** for the first portion **460A** of walls **460**. This provides a U-shaped cross-section (in aft view, as best seen in Fig. 5(c)), defining a lumen **475** in which the boom **500** can be accommodated. In this example the boom **500** is also fixed or otherwise secured to the respective external load coupling portion **450** in a similar manner to the example of Figs. 4 to 4(c), via a first peg **520** (inserted into the end **510** (via the forward end **455** and concave recess **456**, providing a friction fit therebetween) and a second peg **530** inserted into an aft portion **540** of the boom **500** (via the side walls **460**, in particular the respective aft portions thereof, providing a friction fit therebetween).

In the example of Figs. 5, 5(a), 5(b), 5(c), the respective wing-coupling portion **410**, is configured for being joined or otherwise connected to the external aerodynamic surface

205 of the wing **10** such as to be in overlying abutting and load bearing relationship, in which the respective contact surface portion **CP** of the external aerodynamic surface **205** circumscribes the periphery of the aerodynamic component **200**. Thus in this example the contact surface portion **CP** includes (referring to the transverse cross-section of the wing) the leading edge **210**, the full suction surface **220**, the full pressure surface **230** and the trailing end **240** of the external aerodynamic surface **205**.

Referring to Fig. 6, 6(a), 6(b), a composite structure according to a second example of a second aspect of the presently disclosed subject matter, generally designated **400'**, is also similar to the composite structure **400** according to the first example, *mutatis mutandis*, and is also in the form of a load-bearing composite structure, and is also provided for use with an aerodynamic component **200**.

In at least some examples, the load-bearing composite structure **400'** can also be considered as an external "rib" for the aerodynamic component, and further configured for enabling an external load **EL** to be supported on the wing via the load-bearing composite structure **400**.

The composite structure **400'**, in particular wing-coupling portion **410'**, is configured for being joined or otherwise connected to the external aerodynamic surface **205** of the wing **10** such as to be in overlying abutting and load bearing relationship with at least a contact surface portion **CP** of the external aerodynamic surface **205**, in a similar manner to the first example, *mutatis mutandis*. Furthermore, the contact surface portion **CP** includes (referring to the transverse cross-section of the wing) the leading edge **210**, at least a forward portion **225** of the suction surface **220** and at least a forward portion **235** of the pressure surface **230** of the external aerodynamic surface **205**; furthermore, the load-bearing composite structure **400'** is further configured for supporting at least one external load **EL**.

The load-bearing composite structure **400**, in particular wing-coupling portion **410'**, in at least this example is in the form of a generally C-shaped body **420** (in side view) having a functional surface **430'** conforming to the contact surface portion **CP** of the external aerodynamic surface **205**.

In at least some examples, the load-bearing composite structure **400'** is fixed to the wing **10** via connection of the functional surface **430'** of the wing-coupling portion **410'**,

with the contact surface portion **CP** of the external aerodynamic surface **205**. Such connection can be integral, wherein the load-bearing structure **400'** is manufactured together with the wing as a single integral unit, or, alternatively, the load-bearing composite structure **400'** and the wing **10** are manufactured separately, and then the load-bearing composite structure **400'** is affixed to the wing **10**, for example co-bonded with carbon/epoxy fabric splice on the outer wing surface of the aerodynamic component **200**.

In at least this example, and as best seen in Fig. 6(a), the load-bearing composite structure **400'**, in particular the C-shaped body **420'** of wing-coupling portion **410'**, has a hollow structure, in which the outer skin **425'** of C-shaped body **420'** encloses a space **422'**. The outer skin **425'** also has a U-shaped cross-section (in plan view) at least at or near the leading edge **210**, having a base **426'** of the "U" and arms **427'** of the "U".

In at least this example, the base **426'** of the "U" is rounded or otherwise aerodynamically contoured, for example as a leading edge of an airfoil, to minimize drag.

In at least this example, the upper part of the C-shaped body **420'** extends over the suction surface **220** aft as far as the contact portion **CP**, and over the pressure surface **230** up to the trailing end thereof. In particular, the arms **427'** extend over the pressure surface **230** up to the trailing end thereof.

In at least this example, the external-load coupling portion **450'** extends downwardly from the wing-coupling portion **410'**, and comprises a forward end **455'**, side walls **460'** extending aft, co-extensive with the arms **427'**.

The side walls **460'** are spaced by spacing **TC'** (Fig. 6(b)).

Also in this example, the composite structure **400'** is made from composite (i.e., non-metallic) materials. In particular, in this example the wing-coupling portion **410'** is in the form of a structural fairing made of carbon/epoxy fabric layers for example up to 2mm thickness, and having quasi isotropic properties.

Furthermore, in this example the external load coupling portion **450'** is in the form of a structural fairing made of carbon/epoxy fabric layers for example up to 2mm thickness, and having quasi isotropic properties

In this example, the external load **EL** is in the form of an external stores **500'** having a main stores body **510'**, for example in the form of a pod, and that is configured for carrying some payload – for example an engine, a fuel tank, a camera, weapons, and so on. The external load **EL** also comprises a pylon structure **520'** that is configured for being received in the space **490'** enclosed laterally between the side walls **460'**. In operation, the external stores **500'** can be ejected, or replaced,

The external stores **500'** can be affixed or otherwise secured in load bearing relationship with respect to the composite structure **400'**, in particular with respect to the external load coupling portion **450'**, in any suitable manner, reversibly or non-reversibly. In this example, pegs **540'** are each inserted into the pylon structure **520'** via the side walls **460'**, providing a friction fit therebetween.

As with the first example, *mutatis mutandis*, it is also to be noted that the composite structure **400'** is not part of the aerodynamic structure **200** per se, and thus the aerodynamic structure **200** for example in the form of a wing, is designed structurally to meet the loading requirements of thereof even in the absence of the composite structure **400'**. Furthermore, the composite structure **400'** does not require conventional “hard points” on the wing, and thus does not require the wing to have internal spars or ribs. Thus, according to the second aspect of the presently disclosed subject matter the composite structure **400'** can optionally be removed when there is no requirement for this, without adversely affecting the structural integrity of the aerodynamic structure **200** per se.

In the method claims that follow, alphanumeric characters and Roman numerals used to designate claim steps are provided for convenience only and do not imply any particular order of performing the steps.

Finally, it should be noted that the word “comprising” as used throughout the appended claims is to be interpreted to mean “including but not limited to”.

While there has been shown and disclosed examples in accordance with the presently disclosed subject matter, it will be appreciated that many changes may be made therein without departing from the scope of the presently disclosed subject matter as set out in the claims.