According to one embodiment of the invention, a method of constructing a composite structure includes positioning a plurality of forming elements on a skin panel formed from a composite material in a predetermined configuration, disposing a stiffening panel formed from an uncured composite material outwardly from the forming elements to create a plurality of contact regions between the skin panel and the stiffening panel, and curing the skin panel and the stiffening panel to bond the skin panel and the stiffening panel together at the contact regions.
COMPOSITE STRUCTURE AND METHOD FOR CONSTRUCTING SAME

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to the field of composites construction, and more particularly to a composite structure and method for constructing same.

BACKGROUND OF THE INVENTION

Composite structures are desirable in many industries for many applications. For example, aircraft, space, and land/sea vehicles employ a variety of curved and multiple-contoured surface structures in their fabrication. Composite materials are commonly used for these structures because, among other desirable attributes, composite materials have high strength-to-weight ratios. Even so, composite structures formed from composite materials oftentimes need to be stiffened. Therefore, manufacturers of composite structures are continually searching for better and more economical ways of stiffening composite structures.

SUMMARY OF THE INVENTION

According to one embodiment of the invention, a method of constructing a composite structure includes positioning a plurality of forming elements on a skin panel formed from a composite material in a predetermined configuration, disposing a stiffening panel formed from an uncured composite material outwardly from the forming elements to create a plurality of contact regions between the skin panel and the stiffening panel, and curing the skin panel and the stiffening panel to bond the skin panel and the stiffening panel together at the contact regions.

Detailed Description of Embodiments of the Invention

Embodiments of the present invention and their advantages are best understood by referring now to FIGS. 1 through 3D of the drawings, in which like numerals refer to like parts.

FIG. 2 is a perspective view of an aircraft 100 having a panel 102 formed from a composite structure 200 (FIG. 2) constructed according to one embodiment of the present invention. Aircraft 100 may be any suitable aircraft and panel 102 may be any suitable structural panel on aircraft 100, such as a wing panel, a tail panel, or a fuselage panel. Although aircraft 100 is illustrated in FIG. 1, panel 102 may be employed in any suitable aircraft, space, land/sea vehicle, or other machines, devices, or structures formed by composite materials. Oftentimes, structures formed from composite materials need to be stiffened. The following detailed description uses an aircraft application to illustrate one or more embodiments of composite structure 200 manufactured according to the teachings of the present invention. One embodiment of composite structure 200 is illustrated below in conjunction with FIG. 2.

FIG. 2 is a perspective view of an embodiment of composite structure 200. Composite structure 200 includes a skin panel 202, a plurality of forming elements 204, and a stiffening panel 206. Composite structure 200 may also include a plurality of fasteners 208 coupling skin panel 202 and stiffening panel 206.

Skin panel 202 is formed from any suitable composite material, such as graphite epoxy or graphite bis-maleimide (“bmi”). Skin panel 202 may have any suitable number of layers and the fibers that are included in skin panel 202 may be unidirectional, bidirectional, or have any suitable orientation. In the illustrated embodiment, skin panel 202 forms a portion of an outer skin of aircraft 100. For example, skin panel 202 may coincide with a portion of the outer skin of a wing, a tail section, or a fuselage section. Accordingly, skin panel 202 may have any suitable shape, dimensions, and thickness. In addition, skin panel 202 may be substantially flat or may have one or more contours to conform to the shape of a particular portion of aircraft 100.

Forming elements 204 are utilized to impart a predetermined configuration to stiffening panel 206, as described more fully below in conjunction with FIGS. 3A through 3D. The properties and weight of forming elements 204 are selected according to end-use requirements. For example, in some embodiments, forming elements 204 are “flyaway” tooling mandrels formed from a lightweight material suitable for permanent incorporation into composite structure 200, such as low-density, closed cell epoxy or bmi foam, or other suitable polymeric foams, such as carbon
or graphitic foam, having suitable compression strength. Other suitable materials may be such materials as balsa wood, honeycomb structures, or open cell foams. In other embodiments, forming elements 204 are such that after composite structure 200 is formed, forming elements 204 are removable via any suitable meltout or washout technique. In still other embodiments, forming elements 204 may be composed of a thin shell of material that is filled with a meltout or washout type of material where the thin shell is suitable for permanent incorporation into composite structure 200. For example, a thin shell could be formed from a thermoformed plastic, such as ABS, and filled with a remov-able material, such as a water soluble eutectic salt.

FIGS. 3A through 3D. Forming elements 204 may be any suitable size or shape and may form any suitable configuration when positioned on skin panel 202. In the illustrated embodiment, forming elements 204 form a corrugated configuration on skin panel 202; however, other configurations, such as waffle configurations may be formed.

Stiffening panel 206 is formed from any suitable composite material, such as graphite epoxy or graphite bni. To facilitate bonding between stiffening panel 206 and skin panel 202, stiffening panel 206 typically includes a resin that is the same as the resin in skin panel 202; however, other suitable resins may be used. In one embodiment, stiffening panel 206 is formed from a composite material having a plurality of discontinuous fibers so that stiffening panel 206 may be flexible enough to form over forming elements 204, as discussed more fully below in conjunction with FIGS. 3A through 3D. In a particular embodiment, stiffening panel 206 is formed from a composite material having chopped fibers that is sprayed on using well-known spraying techniques onto forming elements 204 and skin panel 202, as discussed more fully below. In other embodiments, the fibers used in the composite material for stiffening panels 206 may be unidirectional, bidirectional, or have any suitable orientation.

Stiffening panel 206 may be formed from any suitable number of layers and may have any suitable size or shape before being placed onto forming elements 204 and skin panel 202. In one embodiment, stiffening panel 206 has the same width as skin panel 202 but is longer than skin panel 202 such that when stiffening panel 206 forms over forming elements 204 it ends up being approximately the same length as skin panel 202. This reduces or eliminates any trimming or finishing operations after composite structure 200 is formed.

Fasteners 208, in one embodiment, are Z pins; however, other suitable fasteners may be used. One purpose of fasteners 208 is for damage resistance. In other words, if a crack starts to develop in composite structure 200 fasteners 208 inhibit crack propagation. As illustrated in FIG. 2, fasteners 208 couple skin panel 202 and stiffening panel 206 at one or more contact regions 210. Fasteners 208 may be inserted by any suitable process, such as pushing or driving while being vibrated with ultrasonic energy.

Now that various elements of composite structure 200 have been described, one method of constructing composite structure 200 is described below in conjunction with FIGS. 3A through 3C.

FIGS. 3A through 3C are perspective elevational views illustrating one method of constructing composite structure 200. The method starts with skin panel 202, as illustrated in FIG. 3A. Skin panel 202, which as described above is formed from any suitable composite material having any suitable dimensions, is provided in either a cured or uncured state. Skin panel 202 is placed on any appropriate or suitably contoured working table or tool (not explicitly shown).

The next step in the method is outlined in FIG. 3B. Forming elements 204 are positioned on skin panel 202 in a predetermined configuration. In the illustrated embodiment, the predetermined configuration is a corrugated configuration; however, other suitable configurations are feasible, such as a waffle configuration (FIG. 3D). Although not illustrated, forming elements 204 may have tapered ends. Forming elements 204 may be located on skin panel 202 by any suitable means, such as a laser positioning locator, a hard positioning template, or by measuring from one or more reference points. After forming elements 204 are positioned in the predetermined configuration, stiffening panel 206 is applied on the top of skin panel 202 and forming elements 204, as illustrated in FIG. 3C.

FIG. 3C shows stiffening panel 206 draped over forming elements 204, thereby forming contact regions 210 between stiffening panel 206 and skin panel 202. For stiffening panel 206 to have the ability to conform to the predetermined configuration created by forming elements 204, stiffening panel 206 is typically formed from an uncured composite material. In addition, the fibers that are part of the composite material that stiffening panel 206 is formed from are, in one embodiment, discontinuous fibers. The fibers may, in other embodiments, be continuous; however, if continuous then the direction of the fibers needs to be in approximately the same direction as the direction of stretching of stiffening panel 206. An important consideration when applying stiffening panel 206 is that substantially no air gaps exist between the bottom surface of stiffening panel 206 and the top surface of skin panel 202. This ensures that adequate bonding takes place between stiffening panel 206 and skin panel 202 at contact regions 210 when the composite material is cured, as described more fully below.

As an option, although not required, adhesive may be applied at contact regions 210 if so desired. However, an important technical advantage of one embodiment of the present invention is that stiffening panel 206 and skin panel 202 may be coupled to one another without the use of adhesives and/or mechanical fasteners. This saves considerable time and money in constructing composite structure 200. In a particular embodiment illustrated by arrow 300, stiffening panel 206 is sprayed on the surface of skin panel 202 and forming elements 204 using any suitable well-known composite spraying techniques. This embodiment may be particularly suitable for stiffening panels that are formed in a waffle configuration, such as stiffening panel 206 illustrated in FIG. 3D.

The next step in the method is to cure skin panel 202 and stiffening panel 206, whereby skin panel 202 and stiffening panel 206 are bonded together at contact regions 210. Any suitable curing techniques well-known in the art of composites forming may be utilized. For example, composite structure 200 may be enveloped in a vacuum bag, a vacuum pulled, and then placed in an autoclave with suitable temperature and pressure to cure the composite materials. The matrix used in the composite materials may be thermo-
setting or thermoplastic. If thermoplastic, then higher curing temperatures would be involved. Composite structure 200 is heated and pressurized for a predetermined time so that the composite material may sufficiently cure. Any trimming or finishing of composite structure 200 may then take place, which ends one method of forming composite structure 200.

[0025] Other methods of curing composite structure 200 may be utilized. For example, two mechanical presses may be used to bond stiffening panel 206 to skin panel 202. In this embodiment, composite structure 200 would be heated to a sufficient temperature before the presses are pressed together for a sufficient time to cure the composite materials. In another embodiment, a resin transfer molding ("RTM") process may be used, wherein dried fabric is used for stiffening panel 206 and skin panel 202 and injected with any suitable resin. Other suitable curing processes may be utilized.

[0026] Although not illustrated in FIGS. 3A through 3C, another step in the method may be to couple skin panel 202 and stiffening panel 206 with fasteners 208 proximate contact regions 210. In this embodiment, skin panel 202 would need to be in an uncured or partially cured state so that skin panel 202 is deformable enough to facilitate the inserting of fasteners 208. In one embodiment, fasteners 208 may be Z-pins, which act to resist any damage during usage of composite structure 200.

[0027] Another option in the method outlined in FIGS. 3A through 3C is to remove forming elements 204 after final curing of skin panel 202 and stiffening panel 206. As outlined above, forming elements 204 would then have to be formed from a material or materials that facilitate their removal. For example, forming elements 204 each may be a rubber bladder filled with sand or eutectic salt with a vacuum pulled on it. Other suitable meltout or washout type of materials may also be used.

[0028] Although embodiments of the invention and their advantages are described in detail, a person skilled in the art could make various alterations, additions, and omissions without departing from the spirit and scope of the present invention as defined by the appended claims.

What is claimed is:

1. A method of constructing a composite structure, comprising:

   positioning a plurality of forming elements on a skin panel formed from a composite material in a predetermined configuration;

   disposing a stiffening panel formed from an uncured composite material outwardly from the forming elements to create a plurality of contact regions between the skin panel and the stiffening panel; and

   curing the skin panel and the stiffening panel to bond the skin panel and the stiffening panel together at the contact regions.

2. The method of claim 1, further comprising removing the forming elements after curing the skin panel and the stiffening panel.

3. The method of claim 1, further comprising coupling the skin panel and the stiffening panel with a plurality of fasteners.

4. The method of claim 3, wherein coupling the skin panel and the stiffening panel with the fasteners comprises coupling the skin panel and the stiffening panel with a plurality of Z-pins proximate the contact regions.

5. The method of claim 1, wherein the skin panel is formed from a composite material selected from the group consisting of a cured composite material and an uncured composite material.

6. The method of claim 1, wherein disposing the stiffening panel comprises spraying a composite material outwardly from the forming elements.

7. The method of claim 1, wherein disposing the stiffening panel formed from the uncured composite material comprises disposing a stiffening panel formed from an uncured composite material having a plurality of discontinuous fibers.

8. The method of claim 1, wherein positioning the forming elements on the skin panel in the predetermined configuration comprises positioning the forming elements in a corrugated configuration.

9. The method of claim 1, wherein positioning the forming elements on the skin panel in the predetermined configuration comprises positioning the forming elements in a waffle configuration.

10. A method of constructing a composite structure, comprising:

    positioning a plurality of forming elements on a skin panel formed from a composite material in a corrugated configuration;

    disposing a stiffening panel formed from an uncured composite material having a plurality of discontinuous fibers outwardly from the skin panel and the forming elements;

    partial-curing the skin panel and the stiffening panel to create a plurality of first contact regions between the skin panel and the stiffening panel and to create a plurality of second contact regions between the forming elements and the stiffening panel;

    coupling the skin panel and the stiffening panel with a plurality of fasteners proximate the first contact regions; and

    final curing the skin panel and the stiffening panel to bond the skin panel and the stiffening panel together at the first contact regions.

11. The method of claim 10, further comprising removing the forming elements after final curing the skin panel and the stiffening panel.

12. The method of claim 11, wherein coupling the skin panel and the stiffening panel with the fasteners comprises coupling the skin panel and the stiffening panel with a plurality of Z-pins proximate the first contact regions.

13. The method of claim 10, wherein the skin panel is formed from a composite material selected from the group consisting of a partially-cured composite material and an uncured composite material.

14. The method of claim 10, wherein disposing the stiffening panel comprises spraying a composite material outwardly from the forming elements.
15. A method of constructing a composite structure, comprising:

positioning a plurality of forming elements on a first surface of a skin panel formed from a composite material selected from the group consisting of a cured composite material and an uncured composite material, the forming elements and the first surface of the skin panel creating a predetermined configuration;

forming a stiffening panel from an uncured composite material having a plurality of discontinuous fibers on a tool having a configuration substantially the same as the predetermined configuration;

heating the stiffening panel to a state sufficient enough to enable handling of the stiffening panel while maintaining its configuration;

disposing the stiffening panel outwardly from the skin panel and the forming elements to create a plurality of first contact regions between the skin panel and the stiffening panel and to create a plurality of second contact regions between the forming elements and the stiffening panel; and

curing the skin panel and the stiffening panel to bond the skin panel and the stiffening panel together at the first contact regions.

16. The method of claim 15, further comprising removing the forming elements after curing the skin panel and the stiffening panel.

17. The method of claim 15, wherein coupling the skin panel and the stiffening panel with the fasteners comprises coupling the skin panel and the stiffening panel with a plurality of Z-pins proximate the contact regions.

18. The method of claim 15, wherein the predetermined configuration is a corrugated configuration.

19. The method of claim 15, wherein the predetermined configuration is a waffle configuration.

20. A composite structure, comprising:

a skin panel formed from a composite material;

a plurality of forming elements positioned on the skin panel in a corrugated configuration;

a stiffening panel formed from an uncured composite material having a plurality of discontinuous fibers disposed outwardly from the skin panel and the forming elements;

a plurality of contact regions created by the skin panel and the stiffening panel;

a plurality of fasteners coupling the skin panel and the stiffening panel proximate the contact regions; and

a plurality of bonding regions proximate the contact regions, the bonding regions created by curing the skin panel and the stiffening panel.

21. The composite structure of claim 20, wherein the fasteners are Z-pins.

22. The composite structure of claim 20, wherein the skin panel is formed from a composite material selected from the group consisting of a cured composite material and an uncured composite material.

23. The composite structure of claim 20, wherein the stiffening panel is sprayed on the forming elements and the skin panel.