CLAIMS

1. A method of repairing a randomly damaged area of a one-piece composite component of an aircraft, the damaged area covering skin and underlying stiffening substructure of the component, the method comprising:

generating a design of a customized composite replacement panel for replacing the damaged area, the design including replacement skin and underlying integrated replacement stiffening substructure; and

fabricating the composite replacement panel according to the design.

2. The method of claim 1, wherein the damaged section is a one-piece composite barrel section of a fuselage.

3. The method of any of claim 1 or 2, wherein the replacement panel is designed to match contour of the damaged area.

4. The method of any of claims 1–3, wherein the damaged area is at least about 90 cm by about 90 cm.

5. The method of any of claims 1–4, wherein generating the design includes generating a panel detail definition for the replacement panel and also a detail definition for elements for fastening the replacement panel to the section.

6. The method of claim 5, wherein the fastening element detail definition defines splice doublers for attaching the replacement panel to the section.

7. The method of claim 5, wherein the design specifies a one-piece replacement panel.

8. The method of claim 5, wherein the design specifies skin and integrated stiffeners, and also at least one excised element.

9. The method of any of claims 1–8, further comprising cutting damaged material from the damaged area, thereby leaving an opening in the component; and installing the fabricated replacement panel in the opening, including mechanically fastening the replacement panel to the component.

10. The method of any of claims 1–9, further comprising repairing small damaged areas

via a bonded repair process.

11. The method of any of claims 1–10, wherein fabricating the replacement panel includes fabricating a custom layup mandrel tool and using the fabricated tool for layup and curing of the replacement panel.

12. The method of claim 11, wherein the mandrel tool is fabricated in a fabrication cell and used in the same fabrication cell to fabricate the replacement panel.

13. The method of claim 12, wherein the fabrication cell includes a dirty section for performing dirty operations on the mandrel tool during fabrication and on the panel after the panel has been cured; and a clean section for composite layup of the replacement panel on the mandrel tool.

14. The method of claim 13, further comprising an end effector positioning system for performing the clean and dirty operations; and a rail system for moving the end effector positioning system and the mandrel tool between the clean and dirty sections.

15. The method of claim 14, wherein the gantry uses a plurality of interchangeable end effectors to perform the clean and dirty operations.

16. The method of any of claims 13–15, wherein operations in the dirty section include trimming and machining of the mandrel tool and the cured panel; and wherein operations in the clean section include panel layup and material cutting.

17. The method of any of claims 11–16, further comprising performing nondestructive inspection of the replacement panel after curing.

18. The method of any of claims 13–17, further comprising a curing section, adjacent the clean section, for curing.

19. The method of any of claims 13–18, wherein:

the mandrel tool is built and machined in the dirty section;

composite material for the replacement panel is laid up on the mandrel tool in the clean section;

the composite material for the panel is cured in the curing section; and

the cured panel is machined in the dirty section.

20. The method of any of claims 11–19, further comprising using the mandrel tool to fabricate composite splice doublers for fastening the replacement panel to the component.

21. The method of any of claims 11–20, wherein fabricating the replacement panel further includes:

mounting a face sheet of the mandrel tool to a rotary support and counterbalancing the face sheet;

using the support to rotate the mandrel tool; and

depositing fabric on the rotating the mandrel tool.

22. The method of claim 21, wherein the rotary support includes a spindle and counterbalancing includes:

attaching weights with spacers to the spindle; and

verifying balance conditions are satisfied to ensure rotational equilibrium within capabilities of a machine that will deposit the reinforcing fibers on the face sheet.

23. The method of claim 21, wherein the rotary support includes a spindle having an adjustable length; and wherein mounting the mandrel tool includes varying length of the spindle to accommodate length of the mandrel tool.

24. The method of any of claims 1–23, wherein designing the replacement panel includes identifying width of tape originally used in the section; and applying a set of rules governing material laydown prior to performing the laydown to determine whether a larger width can be used.

25. The method of claim 24, wherein the rules relate to deviations and defects from laying down material at a given width.

26. The method of either claim 24 or 25, wherein the rules identify a plurality of fabrication cells that have capability to fabricate the panel at the different tape widths.

27. The method of claim 26, wherein the rules identify those fabrication cells that achieve the best balance between (1) laydown machine configuration and tape width; (2) engineering requirements for composite laminate balance and symmetry, (3) structural performance, (4) weight of the replacement panel; and (5) speed of manufacturing the replacement panel.

28. A method of repairing a large area of one-piece composite aircraft component, the method comprising:

generating a design of a customized one-piece composite replacement panel for replacing the damaged area, the design including replacement skin, underlying replacement and stiffening substructure;

fabricating a layup mandrel tool according to the design; and

using the tool to fabricate the replacement panel;

wherein the tool and the replacement panel are fabricated at a single site.

29. The method of claim 28, wherein the site includes a dirty section for performing dirty operations on the mandrel tool during fabrication and on the replacement panel after the panel has been cured; and a clean section for composite layup of the replacement panel on the mandrel tool.

30. The method of claim 29, further comprising a common end effector positioning system for assisting with the clean and dirty operations; and a rail system for moving the end effector positioning system and the mandrel tool between the clean and dirty sections.

31. The method of claim 30, wherein the end effector positioning system uses a plurality of interchangeable end effectors to perform the clean and dirty operations.

32. The method of claim 29, wherein operations in the dirty section include trimming and machining of the mandrel tool and the cured panel; and wherein operations in the clean section include panel layup and material cutting.

33. The method of any of claims 29–32, wherein the site further includes a curing section, adjacent the clean section, for curing the composite layup on the mandrel tool.

34. The method of any of claims 29–33, wherein:

the mandrel tool is built and machined in the dirty section;

a rail system moves the mandrel tool to the clean section;

composite material for the replacement panel is laid up on the mandrel tool in the clean section;

the composite material for the panel is cured on the mandrel tool in the curing section;

the rail system moves the mandrel tool with the cured panel to the dirty section; and

the cured panel is machined in the dirty section.

35. The method of any of claims 28–34, wherein generating the design includes identifying width of tape originally used in laying up the one-piece composite aircraft component; and applying a set of rules governing material laydown to an engineering definition of the replacement panel to determine whether the tape width may be increased prior to material laydown.

36. A method of repairing a damaged one-piece composite fuselage barrel section of an aircraft fuselage, the method comprising:

generating a design of a customized composite replacement panel for replacing a large damaged area of the barrel section, the designed panel including skin and integrated stiffening substructure;

fabricating the replacement panel according to the design;

fabricating fasteners for the replacement panel;

cutting damaged material from the damaged area, thereby leaving an opening in the barrel section; and

installing the fabricated panel in the opening, including using the fasteners to mechanically fasten the fabricated panel to the barrel section.

37. The method of claim 36, further comprising performing non-destructive inspection of the aircraft fuselage to determine location and extent of the damaged area .

38. The method of claim 37, wherein the non-destructive inspection is initiated upon receipt of a report indicating visible damage to the fuselage or a triggering action that might result in damage.

CLAIMS

1. A method of repairing a randomly damaged area of a one-piece composite component of an aircraft, the damaged area covering skin and underlying stiffening substructure of the component, the method comprising:

generating a design of a customized composite replacement panel for replacing the damaged area, the design including replacement skin and underlying integrated replacement stiffening substructure; and

fabricating the composite replacement panel according to the design.

2. The method of claim **1**, wherein the component is a one-piece composite barrel section of a fuselage.

3. The method of claim **1**, wherein the replacement panel is designed to match contour of the damaged area.

4. The method of claim **1**, wherein the damaged area is at least 3 feet×3 feet.

5. The method of claim **1**, wherein generating the design includes generating a panel detail definition for the replacement panel and also a detail definition for elements for fastening the replacement panel to the component.

6. The method of claim **5**, wherein the fastening element detail definition defines splice doublers for attaching the replacement panel to the component.

7. The method of claim **5**, wherein the design specifies a one-piece replacement panel.

8. The method of claim **5**, wherein the design specifies skin and integrated stiffeners, and also at least one excised element.

9. The method of claim **1**, further comprising cutting damaged material from the damaged area, thereby leaving an opening in the component; and installing the fabricated replacement panel in the opening, including mechanically fastening the replacement panel to the component.

10. The method of claim **1**, further comprising repairing small damaged areas via a bonded repair process.

11. The method of claim **1**, wherein fabricating the replacement panel includes fabricating a custom layup mandrel tool and using the fabricated tool for layup and curing of the replacement panel.

12. The method of claim **11**, wherein the mandrel tool is fabricated in a fabrication cell and used in the same fabrication cell to fabricate the replacement panel.

13. The method of claim **12**, wherein the fabrication cell includes a dirty section for performing dirty operations on the mandrel tool during fabrication and on the panel after the panel has been cured; and a clean section for composite layup of the replacement panel on the mandrel tool.

14. The method of claim **13**, further comprising using an end effector positioning system for performing the clean and dirty operations; and moving the end effector positioning system and the mandrel tool between the clean and dirty sections.

15. The method of claim **14**, wherein the end effector positioning system uses a plurality of interchangeable end effectors to perform the clean and dirty operations.

16. The method of claim **13**, wherein the dirty operations in the dirty section include trimming and machining of the mandrel tool and the cured panel; and wherein clean operations in the clean section include panel layup and material cutting.

17. The method of claim **13**, further comprising performing nondestructive inspection of the replacement panel after curing.

18. The method of claim **13**, further comprising a curing section, adjacent the clean section, for curing.

19. The method of claim **18**, wherein:

the mandrel tool is built and machined in the dirty section;

composite material for the replacement panel is laid up on the mandrel tool in the clean section;

the composite material for the panel is cured in the curing section; and

the cured panel is machined in the dirty section.

20. The method of claim **12**, further comprising using the mandrel tool to fabricate composite splice doublers for fastening the replacement panel to the component.

21. The method of claim **11**, wherein fabricating the replacement panel further includes mounting a face sheet of the mandrel tool to a rotary support and counterbalancing the face sheet; using the rotary support to rotate the mandrel tool; and depositing fabric on the face sheet as the mandrel tool is being rotated.

22. The method of claim **21**, wherein the rotary support includes a spindle; and wherein the counterbalancing includes attaching weights with spacers to the spindle; and verifying balance conditions are satisfied to ensure rotational equilibrium within capabilities of a machine that is used to deposit the fabric on the face sheet.

23. The method of claim **22**, wherein the spindle has an adjustable length; and wherein mounting the mandrel tool includes varying length of the spindle to accommodate length of the mandrel tool.

24. The method of claim **1**, wherein generating the design of the replacement panel includes identifying width of tape originally used in the damaged area; and applying a set of rules governing material laydown.

25. The method of claim **24**, wherein the rules relate to deviations and defects from laying down tape at a given width.

26. The method of claim **24**, wherein the rules also identify a plurality of fabrication cells that have capability to fabricate the replacement panel at different tape widths.

27. The method of claim **26**, wherein the rules identify those fabrication cells that achieve a best balance between (1) laydown machine configuration and tape width; (2) engineering requirements for composite laminate balance and symmetry, (3) structural perFormance, (4) weight of the replacement panel; and (5) speed of manufacturing the replacement panel.

28. A method of repairing a damaged one-piece composite fuselage barrel section of an aircraft fuselage, the method comprising:

generating a design of a customized composite replacement panel for replacing a large damaged area of the barrel section, the designed panel including skin and integrated stiffening substructure;

fabricating the replacement panel according to the design;

fabricating fasteners for the replacement panel;

cutting damaged material from the damaged area, thereby leaving an opening in the barrel section; and

installing the fabricated panel in the opening, including using the fasteners to mechanically fasten the fabricated panel to the barrel section.

29. The method of claim **28**, further comprising performing non-destructive inspection of the aircraft fuselage to determine location and extent of the damaged area.

30. The method of claim **29**, wherein the non-destructive inspection is initiated upon receipt of a report indicating visible damage to the fuselage or a triggering action that might result in damage.