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(54) **COMPOSITE AIRFOIL WITH INTEGRAL PLATFORM**

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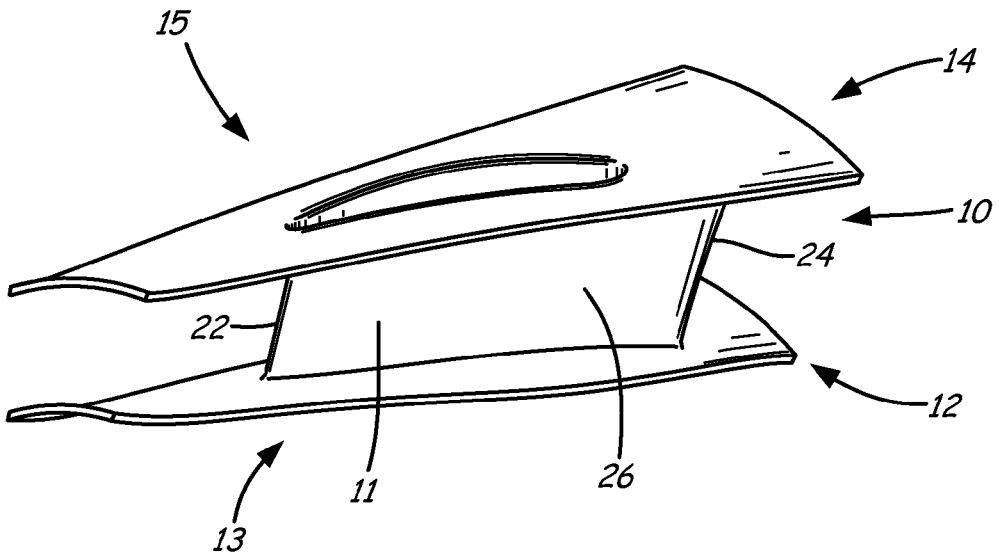
(57) **ABSTRACT**

A method of forming an airfoil with an integrated platform includes: a) providing an airfoil core; b) wrapping a first overwrap ply around the airfoil core; c) darting a first end of the first overwrap ply to allow the overwrap ply to extend perpendicular to the airfoil core to form a first platform; d) filling the darted parts filler plies; e) wrapping a second overwrap ply around the first overwrap ply; f) darting a first end of the second overwrap ply to allow the second overwrap ply to extend adjacent to the first overwrap ply to form the first platform; g) filling the darted parts of the second overwrap ply with one or more filler plies; and h) placing a cap ply in the shape of the platform adjacent to at least one of the first and second overwrap plies. An airfoil with an integrated platform is also disclosed.



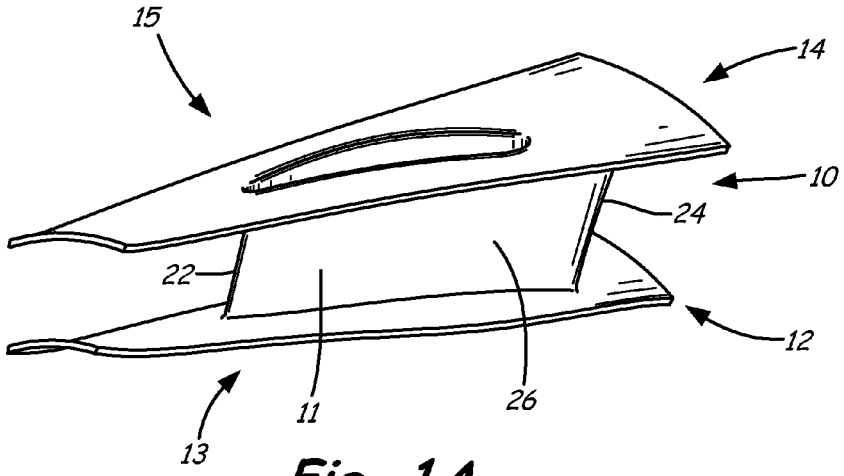



Fig. 1A

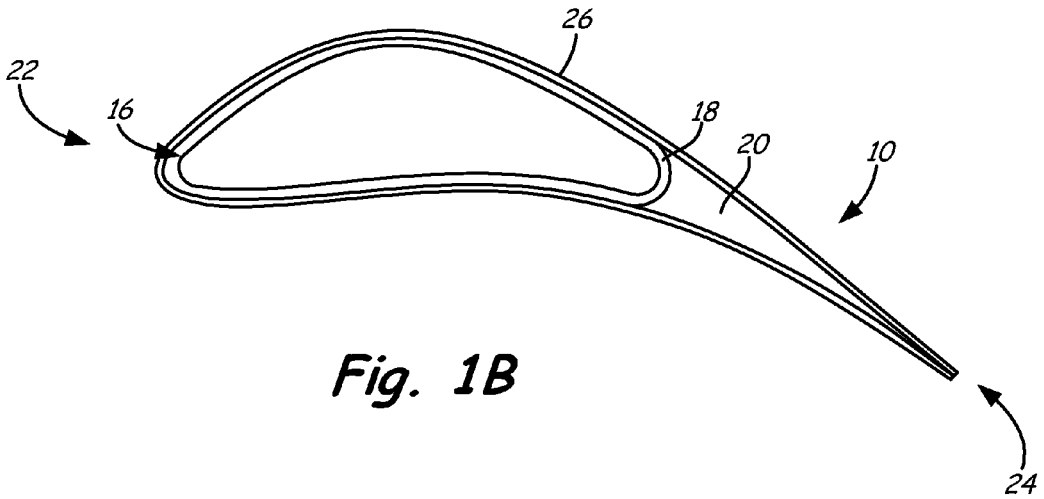



Fig. 1B

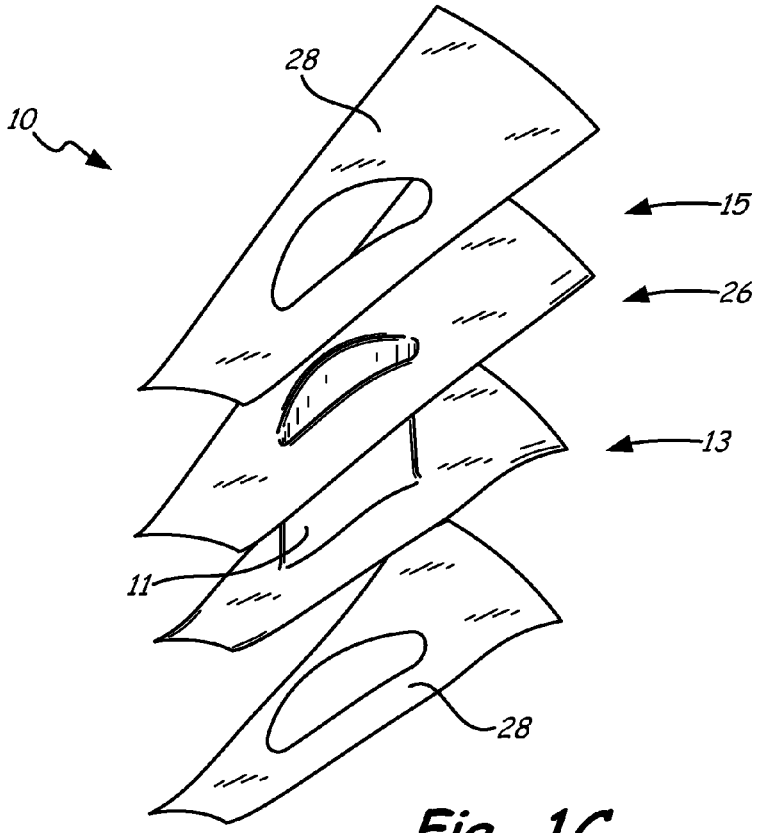



Fig. 1C

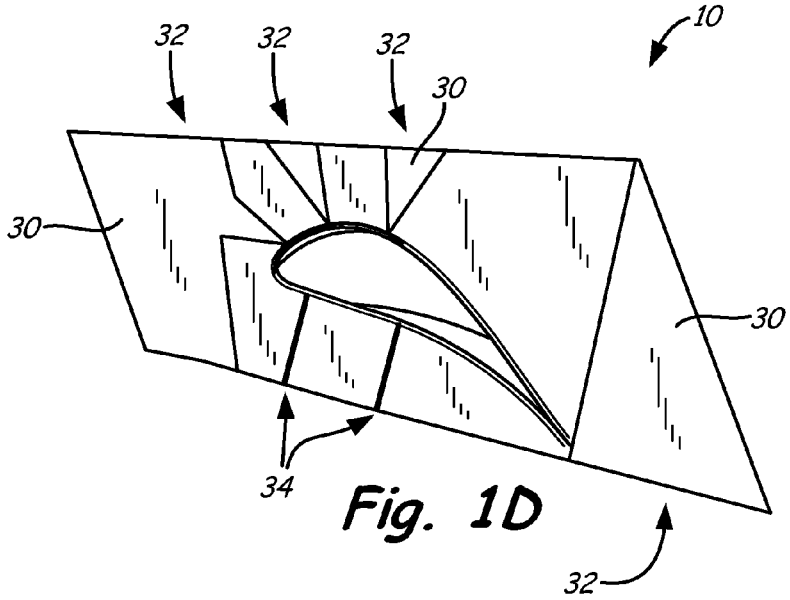



Fig. 1D

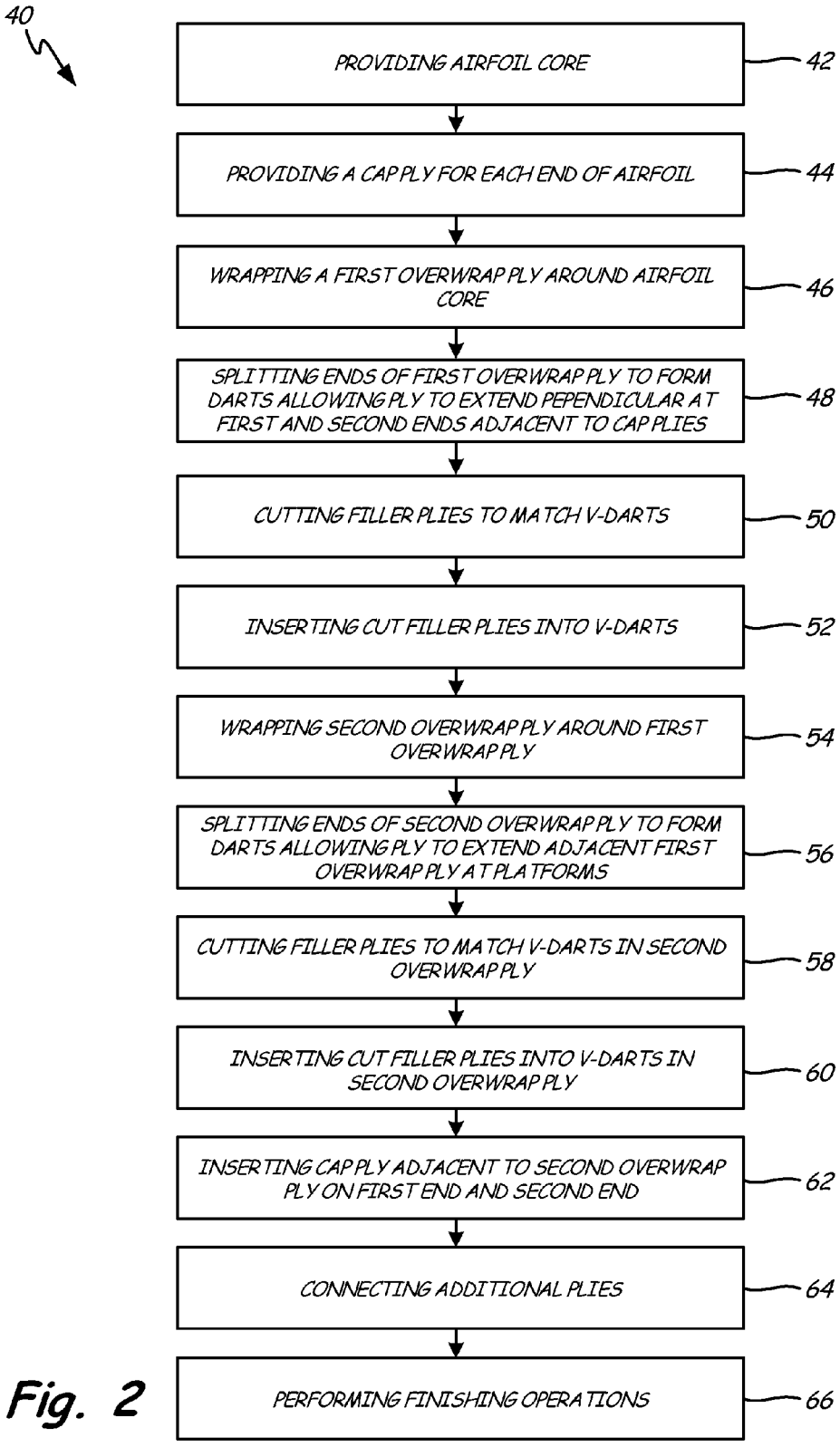

40
PROVIDING AIRFOIL CORE
42
PROVIDING A CAP PLY FOR EACH END OF AIRFOIL
44
WRAPPING A FIRST OVERWRAP PLY AROUND AIRFOIL CORE
46
SPLITTING ENDS OF FIRST OVERWRAP PLY TO FORM DARTS ALLOWING PLY TO EXTEND PEPENDICULAR AT FIRST AND SECOND ENDS ADJACENT TO CAP PLIES
48
CUTTING FILLER PLIES TO MATCH V-DARTS
50
INSERTING CUT FILLER PLIES INTO V-DARTS
52
WRAPPING SECOND OVERWRAP PLY AROUND FIRST OVERWRAP PLY
54
SPLITTING ENDS OF SECOND OVERWRAP PLY TO FORM DARTS ALLOWING PLY TO EXTEND ADJACENT FIRST OVERWRAP PLY AT PLATFORMS
56
CUTTING FILLER PLIES TO MATCH V-DARTS IN SECOND OVERWRAP PLY
58
INSERTING CUT FILLER PLIES INTO V-DARTS IN SECOND OVERWRAP PLY
60
INSERTING CAP PLY ADJACENT TO SECOND OVERWRAP PLY ON FIRST END AND SECOND END
62
CONNECTING ADDITIONAL PLIES
64
PERFORMING FINISHING OPERATIONS
66

Fig. 2

# COMPOSITE AIRFOIL WITH INTEGRAL PLATFORM

## BACKGROUND

**[0001]** Blades and vanes in a gas turbine engine typically require platform features to establish continuity of flowpath. In some applications, these platforms are required to be structural, load bearing features as they transfer aerodynamic loads from the component to the engine static structure.

## SUMMARY

**[0002]** A method of forming an airfoil with an integrated platform includes: a) providing an airfoil core; b) wrapping a first overwrap ply around the airfoil core; c) darting a first end of the first overwrap ply to allow the overwrap ply to extend at an angle to the airfoil core to form a first platform; d) filling the darted parts of the first overwrap ply with one or more filler plies; e) wrapping a second overwrap ply around the first overwrap ply; f) darting a first end of the second overwrap ply to allow the second overwrap ply to extend adjacent to the first overwrap ply to form the first platform; g) filling the darted parts of the second overwrap ply with one or more filler plies; and h) placing a cap ply in the shape of the platform adjacent to at least one of the first and second overwrap plies.

**[0003]** An airfoil with an integrated platform includes an airfoil core with a leading edge and a trailing edge; a plurality of overwrap plies extending along the exterior of the airfoil core and extending at an angle to the airfoil core to form a first platform on a first end of the airfoil, wherein the overwrap plies are split in the first platform area to form at least one of a v-dart and a slit dart; one or more filler plies shaped to fit any v-darts in the overwrap plies; and a plurality of cap plies connecting adjacent to darted overwrap plies in the first platform.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0004]** FIG. **1**A is a perspective view of an airfoil with integrated platforms.

**[0005]** FIG. **1**B is a cross-sectional view of FIG. **1**A through the airfoil.

**[0006]** FIG. **1**C is an exploded view of the airfoil with integrated platforms of FIG. **1**A.

**[0007]** FIG. **1**D is a bottom view of an overwrap ply used in the airfoil of FIG. **1**A.

**[0008]** FIG. **2** is a method of forming the airfoil of FIG. **1**A.

## DETAILED DESCRIPTION

**[0009]** FIG. **1**A is a perspective view of airfoil **10** with integrated platforms **12**, **14** and FIG. **1**B is a cross sectional view of airfoil **10**. FIG. **1**C is an exploded view of airfoil **10** showing one overwrap ply **26** and two cap plies **28** and FIG. **1**D is a bottom view of an overwrap ply **26**. Airfoil **10** includes airfoil body **11**, first platform **12** at first end **13**, second platform **14** at second end **15**, hollow core **16**, internal plies **18**, filler **20**, leading edge **22**, trailing edge **24**, overwrap plies **26**, cap plies **28**, filler plies **30** and darts **32**, **34**.

**[0010]** In the embodiment shown, airfoil **10** is hollow and core **16** of airfoil **10** includes internal plies **18** to form the basic airfoil hollow pressure vessel and filler **20** to fill the portion of airfoil **10** that has a radius smaller than the fibers of internal plies **18** can form without breaking while maintaining the aerodynamic trailing edge shape **24**. Filler **20** can be laminated composite plies stacked vertically, monolithic ceramic inserts, continuous fiber tow oriented in specific directions, chopped composite fibers, or other options that can hold the shape of airfoil **10** and provide sharp edges desired for aerodynamic properties. Airfoil **10** can be used as a static airfoil in various gas turbine engine parts, for example, the mid-turbine frame.

**[0011]** Overwrap plies **26** and internal plies **18** can be two-dimensional fiber architectures. Elongated fibers extend through plies **18**, **26** at specified orientations and give plies **18** and **26** strength. Plies **18** and **26** can vary in size, shape and fiber orientation. Plies **18** and **26** can comprise a woven fabric or a unidirectional material. The fabric may be a plain weave, five harness stain (5HS) weave, 8 harness satin (8HS) weave, or any other common woven fiber architecture. During lay-up, these fabrics may be oriented at any desired angle. The plies, whether fabric or unidirectional, may be woven from a variety of fibers, including, but not limited to, carbon, glass, aramid and ceramic. They may also be used in a dry, tackified, wet lay-up or prepregged state depending on the manufacturing method chosen. Plies **18** and **26** can vary in shape and size. The design or ply layup of plies **18** and **26** can be controlled to manage the locations of specific materials and to manage the locations of the edges of plies **18**, **26** and darts **32**, **34**. A ply drop is formed at the edge of each ply **18** or **26**. Ply drops can provide initiation sites for damage and cracks. The weakest region for laminated composites is often the interlaminar region between plies. High interlaminar stress, such as that caused by operational loads and foreign object strikes, can cause ply delamination that compromises the structural integrity of the structure. The ply drops in airfoil **10** and platforms **12** and **14** formed at the edges of plies **18** and **26**, are staggered and spread apart to prevent crack propagation throughout the rest of the laminate. Cap plies **28** can be the same material as internal plies **18** or overwrap plies **26** or can be different depending on airfoil **10** requirements.

**[0012]** Airfoil **10** with integrated platforms **12**, **14** is formed by wrapping a plurality of overwrap plies **26** over core **16** and forming platforms **12**, **14** with overwrap plies **26** and ply caps **28**. A first overwrap ply **26** is wrapped around core **16**. Overwrap ply **26** is then cut, in the case of a fabric, or separated in the case of a unidirectional material, to form darts **32**, **34**, allowing it to extend at an angle, for example, perpendicularly, from airfoil body **11** at first end **13** and second end **15**. Darts can be v-darts **32** or slit darts **34**. V-darts **32** are necessary at locations of convex curvature around the perimeter of the airfoil, forcing a cut or separation of tows to allow overwrap ply **26** to extend at an angle from airfoil body **11**. V-darts **32** can then be filled with filler plies **30** cut to the shape of v-darts **32**. Slit darts **34** are required at locations of concave curvature around the perimeter of the airfoil, necessitating that material be removed to allow the ply to cover the desired area without overlapping itself. Another overwrap ply **26** is then wrapped around first overwrap ply **26** and darted to lay adjacent to first overwrap ply **26** on airfoil body **11** and platforms **12** and **14**. Darts **32**, **34** are staggered between adjacent overwrap plies **26** so that darts **32**, **34** do not lay on top of each other, and create weak fault lines in platforms **12**, **14**. Airfoil **10** can be made of a plurality of overwrap plies **26**, for example ten, intermixed with cap plies **28** in platforms **12**, **14**.

**[0013]** Cap plies **28** are cut in the shape of platforms **12**, **14** to sit adjacent to one or more overwrap plies **26** in platforms **12**, **14** to provide a continuous reinforcement layer in platforms **12**, **14**. Cap plies **28** can be placed, for example,

between every two or three overwrap plies **26**. Cap plies **28** can also be placed on the gas flow path side of airfoil **10** to give a smooth air flow surface.

**[0014]** Darts **32**, **34** allow overwrap plies **26** to lay flat and not wrinkle or bunch when extending perpendicularly from airfoil body **11**. Filler plies **30** are inserted to fill in v-darts **32**, and cap plies **28** are used to further reinforce platforms **12**, **14**.

**[0015]** FIG. **2** shows method **40** of forming airfoil **10** of FIG. **1**A. Method **40** includes the steps of providing an airfoil core (step **42**), providing a cap ply for each end of the airfoil (step **44**), wrapping a first overwrap ply around the airfoil core (step **46**), cutting or separating the ends of the first overwrap ply to form darts which allow the ply to extend at an angle to the airfoil core at first and second ends (step **48**), cutting filler plies to match v-darts (step **50**), inserting the cut filler plies into the v-darts (step **52**), wrapping a second overwrap ply around the first overwrap ply (step **54**), cutting or separating the ends of the second overwrap ply to form darts which allow the ply to extend adjacent to the first overwrap ply at the platforms (step **56**), cutting filler plies to match the v-darts in the second overwrap ply (step **60**), inserting cap plies adjacent to second overwrap ply on first end and second end (step **62**), connecting additional plies (step **64**), and performing additional finishing operations (step **66**).

**[0016]** Providing a hollow airfoil core **16** (step **42**) can involve wrapping plies around an existing core tool or obtaining a core by some other means. Airfoil core **16** can vary in shape, size and properties, but generally must form at least a portion of airfoil for overwrap plies **26** to connect around.

**[0017]** Providing a cap ply for each end of the airfoil (step **44**) involves obtaining two cap plies **28**, one in the shape of first platform **12** and one in the shape of second platform **14**. These will act as the airflow surface plies for platforms **12**, **14**, giving a smooth airflow surface for greater aerodynamic properties. Cap plies can be made or cut from the same material as overwrap plies, or can be different materials depending on airfoil **10** requirements.

**[0018]** Wrapping a first overwrap ply **26** around airfoil core (step **46**) can involve using a wet lay-up, a prepregged material or a tackifier on overwrap ply **26** to allow it to stick to the core when wrapping. The tackifier is compatible with the matrix material used in composite airfoil **10**.

**[0019]** Cutting or separating the ends of first overwrap ply **26** to form darts **32**, **34**, allowing ply to extend at an angle to first and second ends **13**, **15** adjacent to cap plies **28** (step **48**) can be done using any cutting tool that works with the material of overwrap ply **26**. The large radius of curvature of airfoil **10** produces wrinkling of the fabric as it is extended at an angle to airfoil body **11** to form platforms **12**, **14**. In areas where there is too much fabric, slit darts **34** are cut to remove fabric from overwrap ply **26**. In areas where there is too little fabric, v-darts **32** are cut. Filler plies **30** are then cut to match the shapes of v-darts **32** (step **50**) and inserted into v-darts **32** to form a flat surface on platforms **12**, **14** (step **52**).

**[0020]** Another overwrap ply **26** is then wrapped around first overwrap ply (step **54**), the ends of the second overwrap ply are cut or separated (in the same manner as first overwrap ply **26**) to form darts allowing the second overwrap ply to extend adjacent to the first overwrap ply at platforms (step **56**). Darts **32**, **34** between adjacent overwrap plies **26** are staggered to avoid weak fault lines, which could lead to weaker overall platform **12**, **14**. Filler plies **30** are then cut to match v-darts in second overwrap ply (step **60**), as discussed in relation to first overwrap ply **26**.

**[0021]** Inserting a cap ply **28** adjacent to the second overwrap ply on first end **13** and second end **15** (step **62**) gives platforms **12**, **14** a layer of continuous fabric reinforcement. This increases overall strength of platforms **12**, **14**.

**[0022]** Additional plies **18**, **26**, **28** can be connected (step **64**) to form airfoil **10** in the same manner as in steps **46** through **62**. These steps can be performed any number of times, or may be performed in any order, depending on the desired requirements for airfoil **10**. One example could include an airfoil **10** with five internal pressure vessel plies **18**, five overwrap plies **26** and cap plies **28** between every two platform plies **18**, **26**. The outer edges of each side of platforms **12**, **14** can be covered with cap plies **28** to provide a smooth, continuous outer surface. Alternative embodiments could use cap plies **28** between every overwrap ply **26**, between every three overwrap plies **26** or not at all.

**[0023]** Performing additional finishing operations (step **66**) can include curing airfoil **10**, machining airfoil **10** and/or performing controlled high temperature cycles. To cure airfoil **10** with integral platforms **12**, **14**, a Resin Transfer Molding (RTM) process may be used in which internal plies **18**, overwrap plies **26**, cap plies **28** and filler **20** are placed in a mold, injected with resin and cured. Example resins include but are not limited to epoxy resins and epoxy resins containing an additive, such as rubber. Alternatively, airfoil plies **18**, **26**, **28** can be pre-impregnated composites, (i.e. "prepregs") such that resin is not directly added to the mold. In a ceramic matrix composite airfoil **10**, a pre-ceramic polymer is used as that matrix material. Once airfoil **10** is cured, it can be put through high temperature cycles in a controlled environment that convert the pre-ceramic polymer into a ceramic. This conversion causes the volume to change, resulting in a porous material. The part is then put in another bath of the matrix to fill any crack or voids caused by the change of volume, followed by another controlled high temperature cycle. This can be repeated a number of times until airfoil **10** reaches the desired density. Machining can be done at various steps as well.

**[0024]** Method **40** allows for the forming of airfoil **10** with integral platforms **12**, thereby providing an airfoil with increased strength and stability for handling and transferring loads. Darts **32**, **34** allow for extending plies to form platforms **12**, **14** integrally and preventing wrinkling of the fabric as plies are extended perpendicularly to airfoil body **11**. Cap plies **28** provide a continuous surface to reinforce platforms **12**, **14** and overall airfoil **10** and can provide a smooth surface for increased aerodynamic performance.

**[0025]** While airfoil **10** core **16** is shown as a hollow airfoil with internal plies **18** and filler **20**, core **16** can be made of other materials, such as metal and/or can be solid depending on system requirements. While FIGS. **1**A-**1**D show a static airfoil with two platforms, the airfoil could also have only one platform and could be a rotating airfoil or it could have two platforms and multiple airfoils. Although airfoil platforms **12**, **14** are shown as being made by extending overwrap plies **26** (and using cap plies **28**), inner plies (if used in airfoil construction) can also be extended and darted in the same manner as overwrap plies **26** to form platforms **12**, **14**. While internal plies have been discussed to be constructed from individually wrapped plies with staggered seams, internal plies **18** can be constructed by continuously wrapping internal plies around core **16** as many times as needed, reducing the number of overall seams.

**[0026]** A method of forming an airfoil with an integrated platform includes: a) providing an airfoil core; b) wrapping a first overwrap ply around the airfoil core; c) darting a first end of the first overwrap ply to allow the overwrap ply to extend at an angle to the airfoil core to form a first platform; d) filling the darted parts of the first overwrap ply with one or more filler plies; e) wrapping a second overwrap ply around the first overwrap ply; f) darting a first end of the second overwrap ply to allow the second overwrap ply to extend adjacent to the first overwrap ply to form the first platform; g) filling the darted parts of the second overwrap ply with one or more filler plies; and h) placing a cap ply in the shape of the platform adjacent to at least one of the first and second overwrap plies.

**[0027]** Additional and/or alternative embodiments include: placing a cap ply adjacent to the first overwrap ply to form the surface of the platform flow path; repeating steps (b)-(h) at least one time; darting a second end of the first overwrap ply to allow it to extend at an angle to the airfoil core to form a second platform; filling the darted parts of the second overwrap ply with one or more filler plies; step (f) further comprising darting a second end of the second overwrap ply to allow it to extend at an angle to the airfoil core adjacent to the first ply to form the second platform; step (g) further comprising filling the darted portions of the second end of the second overwrap ply with one or more filler plies; step (h) further comprising placing a second cap ply in the shape of the platform adjacent to the second overwrap ply forming the second platform; repeating steps (b)-(h) at least one time; step (a) further comprising wrapping internal plies around the airfoil core; and inserting filler material; and/or extending the internal plies to form a part of the first platform.

**[0028]** An airfoil with an integrated platform includes an airfoil core with a leading edge and a trailing edge; a plurality of overwrap plies extending along the exterior of the airfoil core and extending at an angle to the airfoil core to form a first platform on a first end of the airfoil, wherein the overwrap plies are cut in the first platform area to form at least one of a v-dart and a slice dart; one or more filler plies shaped to fit any v-darts in the overwrap plies; and a plurality of cap plies connecting adjacent to darted overwrap plies in the first platform.

**[0029]** Additional and/or alternative embodiments include a second platform formed by darting the overwrap plies on a second end of the airfoil to include at least one of v-darts and slice darts; the second platform further comprising one or more filler plies to fit into the areas of the v-darts in the second platform; and one or more cap plies to fit adjacent to darted overwrap plies in the second platform; locally staggering the darts; at least one of the cap plies being located between every two darted plies; a cap ply forming the flow path surface on the first platform; and/or the airfoil core being hollow.

**[0030]** A method of forming an airfoil includes (a) providing an airfoil core; (b) wrapping internal plies around the airfoil core; (c) inserting filler material; (d) wrapping a first overwrap ply around the internal plies and filler material; (e) darting the first overwrap ply in one or more places at a first end to allow the first overwrap ply to extend at an angle to the airfoil core to form a first platform; (f) inserting one or more first filler plies in any darts formed from darting the first overwrap ply; (g) covering the first overwrap ply with a second overwrap ply; (h) darting the second overwrap ply in one or more places at the first end to allow it to extend at an angle to the airfoil core adjacent to the first overwrap ply on the first platform; (i) inserting one or more second filler plies into any darts formed from darting the second overwrap ply; and (j) attaching a first cover ply in the shape of the first platform adjacent to one or more of the first and second plies.

**[0031]** Additional and/or alternative embodiments include performing steps (d)-(j) a plurality of times; extending internal plies to the first platform; forming a pressure vessel from the internal plies and forming a sharp trailing edge from filler; (i) darting the overwrap ply in one or more places at a second end to allow it to extend at an angle to the airfoil core to form a second platform; (j) inserting one or more third filler plies in any darts formed from darting the first overwrap ply at the second end; (k) darting the second overwrap ply in one or more places at the second end to allow it to extend perpendicular to the airfoil core adjacent to the first overwrap ply on the second platform; (1) inserting one or more fourth filler plies into any darts formed from darting the second overwrap ply at the second end; and (m) attaching a second cover ply in the shape of the second platform adjacent to one or more of the first and second plies; and/or performing steps (b)-(m) a plurality of times.

**[0032]** While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

**1**. A method of forming an airfoil with an integrated platform, the method comprising:

a) providing an airfoil core;

b) wrapping a first overwrap ply around the airfoil core;

c) darting a first end of the first overwrap ply to allow the overwrap ply to extend at an angle to the airfoil core to form a first platform;

d) filling the darted parts of the first overwrap ply with one or more filler plies;

e) wrapping a second overwrap ply around the first overwrap ply;

f) darting a first end of the second overwrap ply to allow the second overwrap ply to extend adjacent to the first overwrap ply to form the first platform;

g) filling the darted parts of the second overwrap ply with one or more filler plies; and

h) placing a cap ply in the shape of the platform adjacent to at least one of the first and second overwrap plies.

**2**. The method of claim **1**, and further comprising:

placing a cap ply adjacent to the first overwrap ply to form the surface of the platform flow path.

**3**. The method of claim **1**, wherein steps (b)-(h) are repeated at least one time.

**4**. The method of claim **1**, wherein step (c) further comprises:

darting a second end of the first overwrap ply to allow it to extend at an angle to the airfoil core to form a second platform.

**5**. The method of claim **4**, wherein step (d) further comprises:

filling the darted parts of the second overwrap ply with one or more filler plies.

**6**. The method of claim **5**, wherein step (f) further comprises:

darting a second end of the second overwrap ply to allow it to extend at an angle to the airfoil core adjacent to the first ply to form the second platform.

**7**. The method of claim **6**, wherein step (g) further comprises:

filling the darted portions of the second end of the second overwrap ply with one or more filler plies.

**8**. The method of claim **7**, wherein step (h) further comprises:

placing a second cap ply in the shape of the platform adjacent to the second overwrap ply forming the second platform.

**9**. The method of claim **8**, wherein steps (b)-(h) are repeated at least one time.

**10**. The method of claim **1**, where step (a) further comprises:

wrapping internal plies around the airfoil core; and

inserting filler material.

**11**. The method of claim **10**, wherein the internal plies are extended to form a part of the first platform.

**12**. An airfoil with an integrated platform comprising:

an airfoil core with a leading edge and a trailing edge;

a plurality of overwrap plies extending along the exterior of the airfoil core and extending at an angle to the airfoil body to form a first platform on a first end of the airfoil, wherein the overwrap plies are split in the first platform area to form at least one of a v-dart and a slit dart;

one or more filler plies shaped to fit any v-darts in the overwrap plies; and

a plurality of cap plies connecting adjacent to darted overwrap plies in the first platform.

**13**. The airfoil of claim **12**, and further comprising:

a second platform formed by darting the overwrap plies on a second end of the airfoil to include at least one of v-darts and slice darts.

**14**. The airfoil of claim **13**, wherein the second platform further comprises:

one or more filler plies to fit into the areas of the v-darts in the second platform; and

one or more cap plies to fit adjacent to darted overwrap plies in the second platform.

**15**. The airfoil of claim **12**, wherein the darts are locally staggered.

**16**. The airfoil of claim **12**, wherein at least one of the cap plies is located between every two darted plies.

**17**. The airfoil of claim **12**, wherein a cap ply forms the flow path surface on the first platform.

**18**. The airfoil of claim **12**, wherein the airfoil core is a hollow core.

**19**. A method of forming an airfoil comprising:

(a) providing an airfoil core;

(b) wrapping internal plies around the airfoil core;

(c) inserting filler material;

(d) wrapping a first overwrap ply around the internal plies and filler material;

(e) darting the first overwrap ply in one or more places at a first end to allow the first overwrap ply to extend at an angle to the airfoil core to form a first platform;

(f) inserting one or more first filler plies in any darts formed from darting the first overwrap ply;

(g) covering the first overwrap ply with a second overwrap ply;

(h) darting the second overwrap ply in one or more places at the first end to allow it to extend at an angle to the airfoil core adjacent to the first overwrap ply on the first platform;

(i) inserting one or more second filler plies into any darts formed from darting the second overwrap ply; and

(j) attaching a first cover ply in the shape of the first platform adjacent to one or more of the first and second plies.

**20**. The method of claim **19**, wherein steps (d)-(j) are performed a plurality of times.

**21**. The method of claim **19**, wherein the internal plies extend to the first platform.

**22**. The method of claim **21**, wherein the internal plies form a pressure vessel and the filler forms a sharp trailing edge.

**23**. The method of claim **19**, and further comprising:

(i) darting the overwrap ply in one or more places at a second end to allow it to extend at an angle to the airfoil core to form a second platform;

(j) inserting one or more third filler plies in any darts formed from darting the first overwrap ply at the second end;

(k) darting the second overwrap ply in one or more places at the second end to allow it to extend perpendicular to the airfoil core adjacent to the first overwrap ply on the second platform;

(l) inserting one or more fourth filler plies into any darts formed from darting the second overwrap ply at the second end; and

(m) attaching a second cover ply in the shape of the second platform adjacent to one or more of the first and second plies.

**24**. The method of claim **23**, wherein steps (b)-(m) are performed a plurality of times.

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