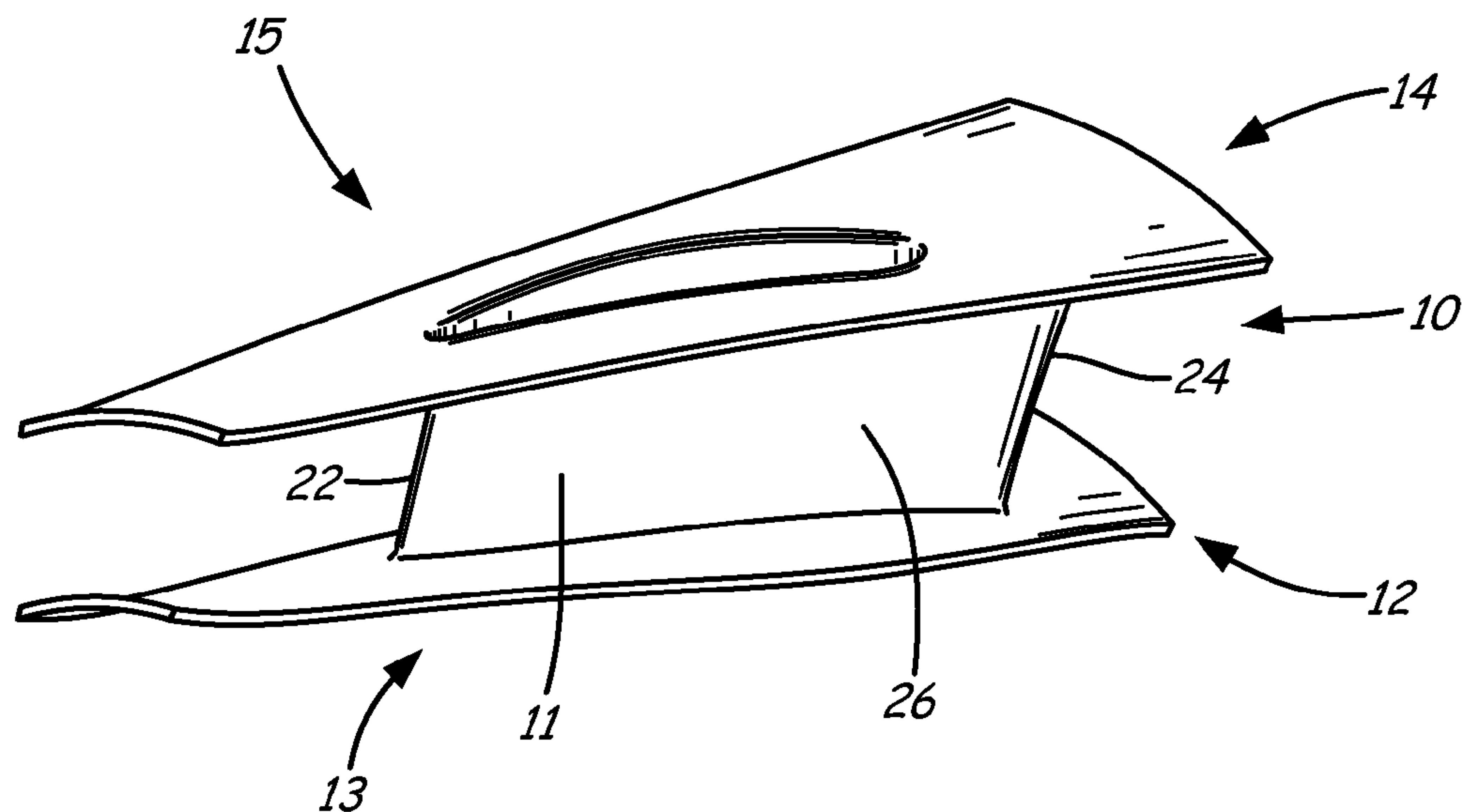




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(19) **United States**(12) **Patent Application Publication**
Duelm et al.(10) **Pub. No.: US 2014/0010662 A1**(43) **Pub. Date: Jan. 9, 2014**(54) **COMPOSITE AIRFOIL WITH INTEGRAL PLATFORM**(75) Inventors: **Shelton O. Duelm**, Wethersfield, CT (US); **Erica L. Prevost**, Vernon, CT (US); **Conway Chuong**, Manchester, CT (US)(73) Assignee: **UNITED TECHNOLOGIES CORPORATION**, Hartford, CT (US)(21) Appl. No.: **13/540,872**(22) Filed: **Jul. 3, 2012****Publication Classification**(51) **Int. Cl.**
F01D 5/14 (2006.01)(52) **U.S. Cl.**CPC **F01D 5/147** (2013.01)USPC **416/230**; 29/889.6(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.



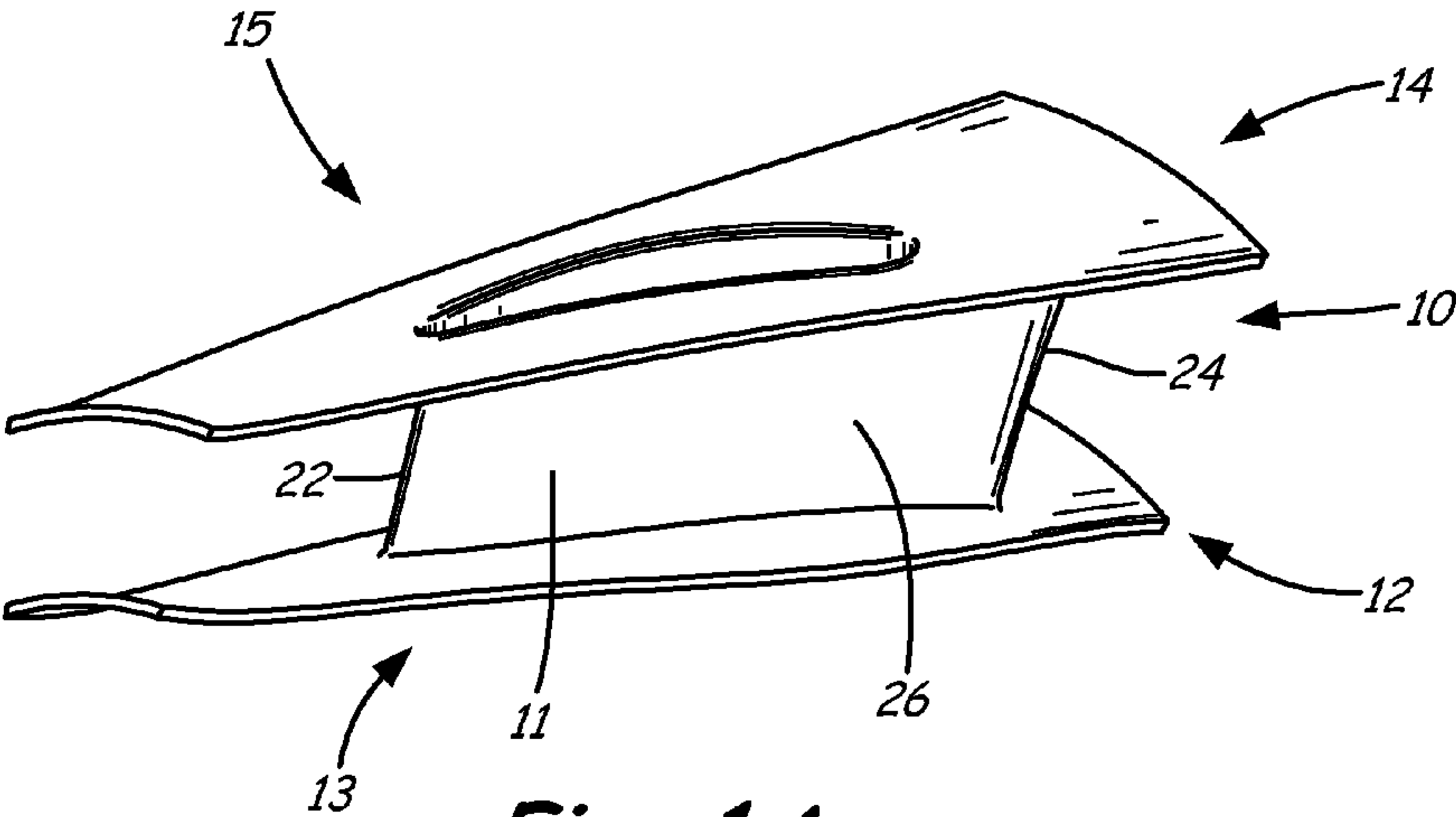


Fig. 1A

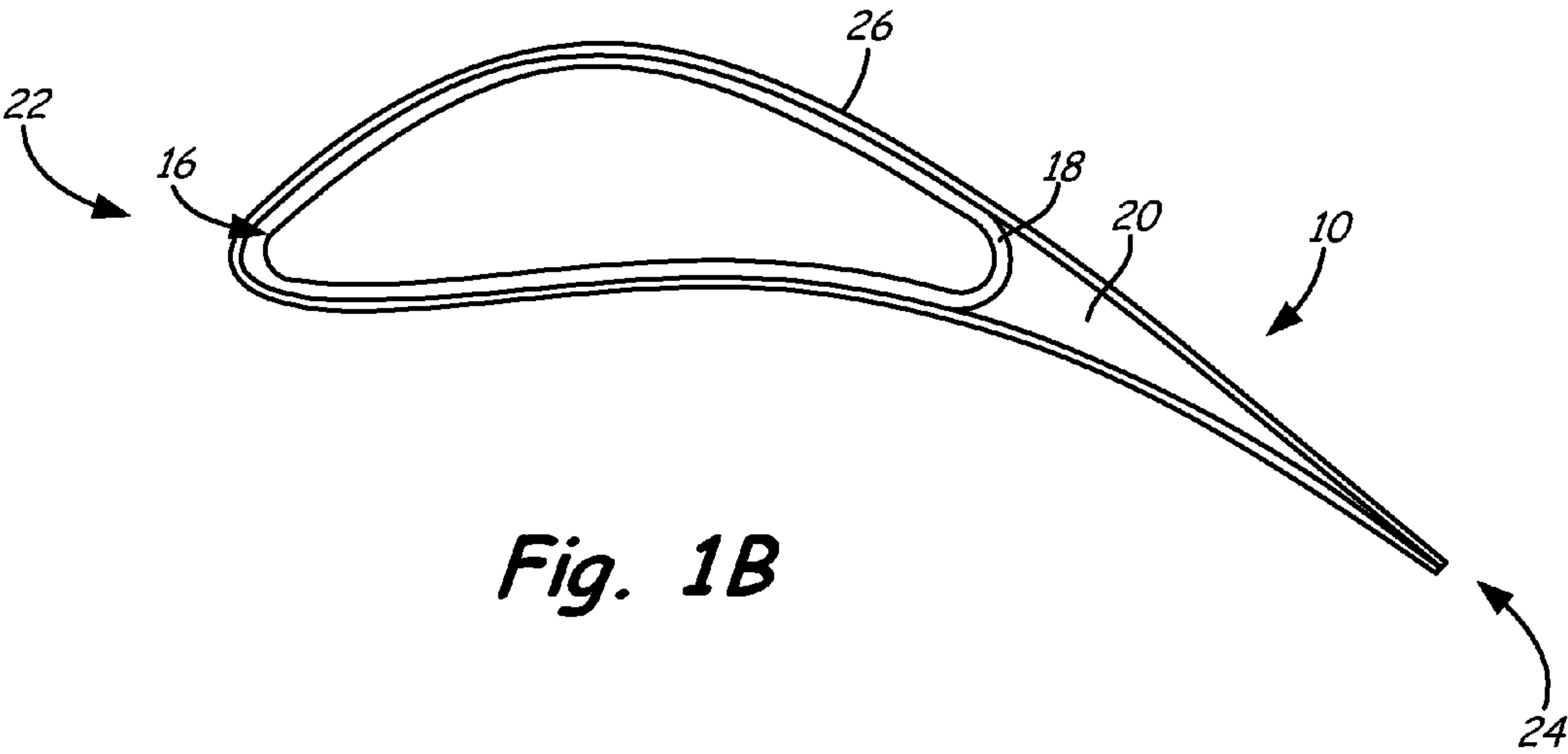


Fig. 1B

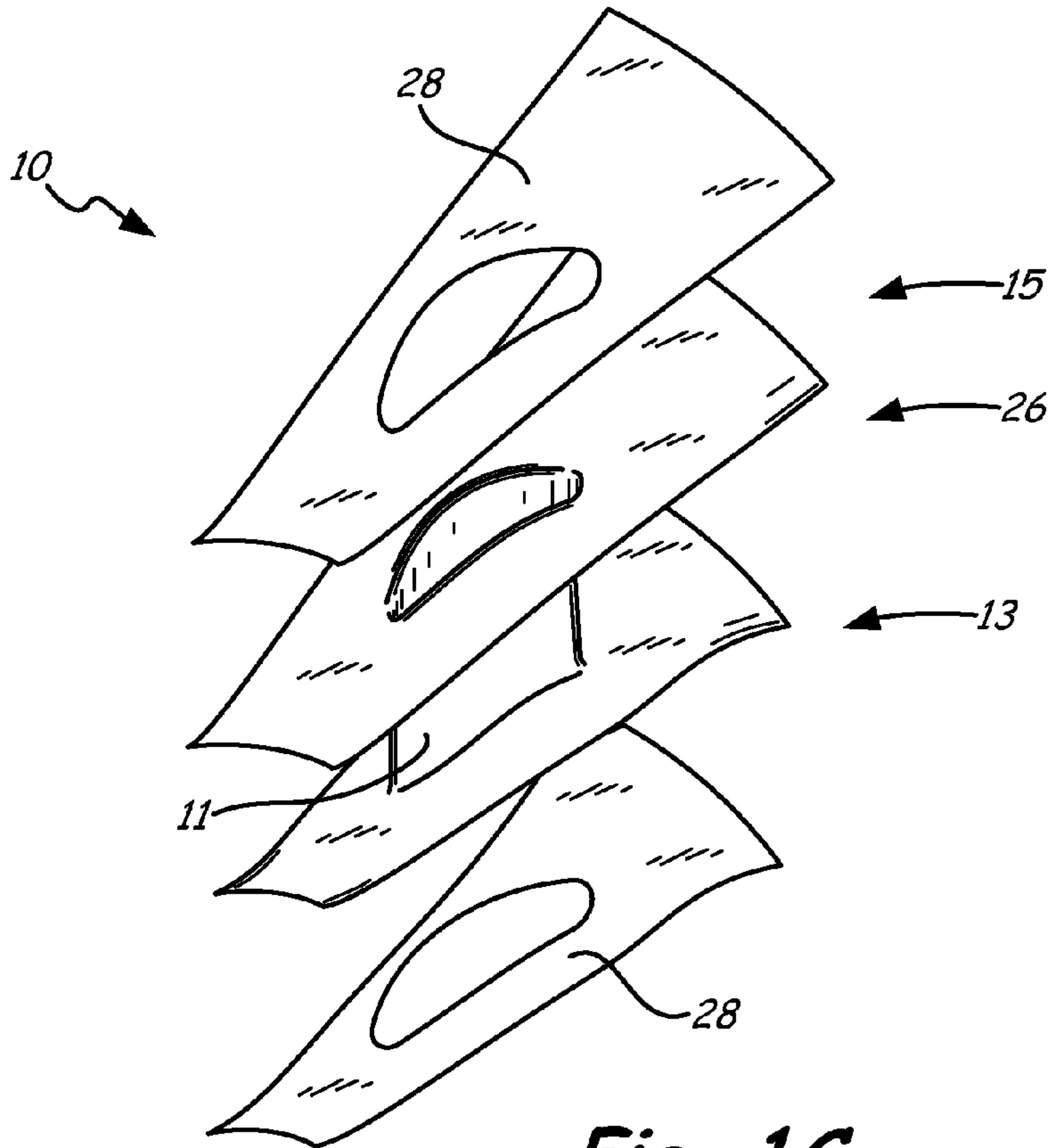


Fig. 1C

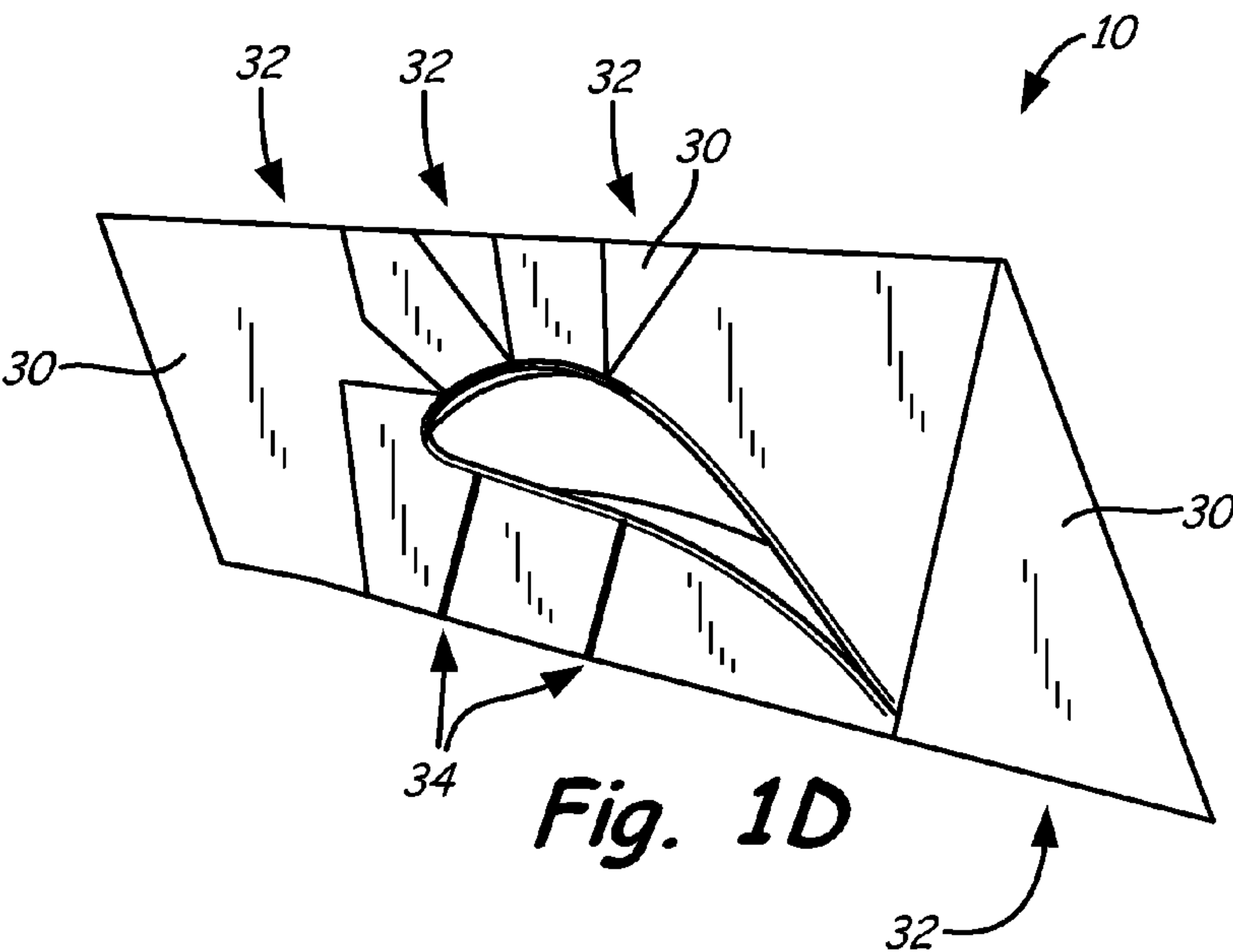
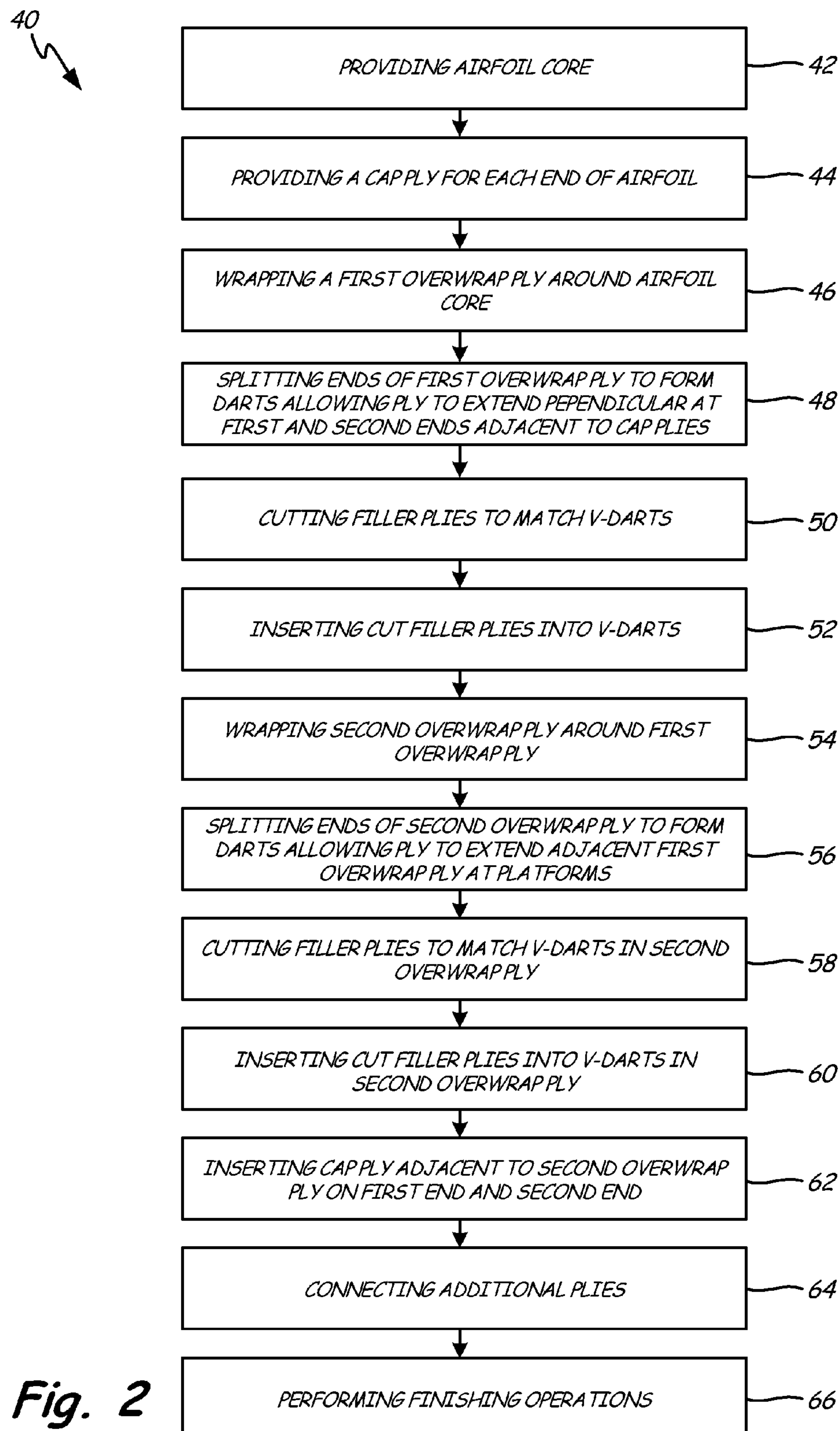


Fig. 1D



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. 1A is a perspective view of an airfoil with integrated platforms.

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

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

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

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

DETAILED DESCRIPTION

[0009] FIG. 1A is a perspective view of airfoil 10 with integrated platforms 12, 14 and FIG. 1B is a cross sectional view of airfoil 10. FIG. 1C is an exploded view of airfoil 10 showing one overwrap ply 26 and two cap plies 28 and FIG. 1D 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. 1A. 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. 1A-1D 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; (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; 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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