US Patent & Trademark Office
Patent Public Search | Text View

United States Patent Application Publication	20250257660
Kind Code	A1
Publication Date	August 14, 2025
Inventor(s)	Kray; Nicholas Joseph et al.

COMPOSITE AIRFOIL ASSEMBLY HAVING A COMPOSITE AIRFOIL AND SPAR

Abstract

A composite airfoil assembly has a composite airfoil, a spar, and a wrap. The composite airfoil has an outer wall and a composite skin. The outer wall extends between a root and a tip. The outer wall defines an interior. The composite skin at least partially defines the outer wall. The spar having a spar centerline axis, a stem, a base, and a transition interconnecting the base and the stem.

Inventors: **Kray; Nicholas Joseph (Mason, OH), Suresh; Balaraju (Bangalore, IN), Bryant, JR.; Gary Willard (Loveland, OH), Yadav; Abhijeet Jayshingrao (Bangalore, IN), Worthoff; Frank (West Chester, OH), Jain; Nitesh (Bangalore, IN)**

Applicant: **GENERAL ELECTRIC COMPANY** (Schenectady, NY)

Family ID: **1000007887043**

Appl. No.: **18/653052**

Filed: **May 02, 2024**

Foreign Application Priority Data

IN	202411010190	Feb. 14, 2024

Publication Classification

Int. Cl.: **F01D5/14** (20060101); **F01D5/30** (20060101)

U.S. Cl.:

CPC **F01D5/147** (20130101); **F01D5/3092** (20130101); F05D2220/30 (20130101)

Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS
[0001] This application takes priority to Indian Patent Application number 202411010190, filed Feb. 14, 2024, which is incorporated herein by reference in its entirety.
TECHNICAL FIELD
[0002] The disclosure generally relates to a composite airfoil assembly, and more specifically to a composite airfoil assembly having a composite airfoil and a spar.
BACKGROUND
[0003] Turbine engines, and particularly gas or combustion turbine engines, are rotary engines that extract energy from a flow of gases passing through a fan with a plurality of fan blades, then into the engine through a series of compressor stages, which include pairs of rotating blades and stationary vanes, through a combustor, and then through a series of turbine stages, which include pairs of rotating blades and stationary vanes. The blades are mounted to rotating disks, while the vanes are mounted to stator disks.
[0004] During operation, air is brought into the compressor section through the fan section where it is then pressurized in the compressor and mixed with fuel and ignited in the combustor for generating hot combustion gases which flow downstream through the turbine stages where the air is expanded and exhausted out an exhaust section. The expansion of the air in the turbine section is used to drive the rotating sections of the fan section and the compressor section. The drawing in of air, the pressurization of the air, and the expansion of the air is done, in part, through rotation of various rotating blades mounted to respective disks throughout the fan section, the compressor section, and the turbine section, respectively. The rotation of the rotating blades imparts mechanical stresses along various portions of the blade; specifically, where the blade is mounted to the disk.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0005] A full and enabling disclosure of the present disclosure, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:
[0006] FIG. **1** is a schematic cross-sectional view of a turbine engine, the turbine engine being an unducted or open rotor turbine engine in accordance with an exemplary embodiment of the present disclosure.
[0007] FIG. **2** is a schematic illustration of a composite airfoil assembly suitable for use within the turbine engine of FIG. **1**, the composite airfoil assembly including a composite airfoil, a trunnion, a spar, and a wrap.
[0008] FIG. **3** is a schematic cross-sectional view of a portion of the composite airfoil assembly as seen from sectional line III-III of FIG. **2**, further illustrating a stem and a base of the spar with a transition being provided therebetween, the wrap provided over the transition, the spar having a centerline axis.
[0009] FIG. **4** is a schematic cross-sectional view of a half of the wrap of FIG. **3** as seen along a plane extending along the centerline axis of the spar, further illustrating a first region with a first thickness and a second region with a second thickness.
[0010] FIG. **5** is schematic view of the wrap of FIG. **3** as seen along a plane extending circumferentially with respect to the centerline axis, the wrap being flattened and further illustrating the second region defining a perimeter of the wrap.
[0011] FIG. **6** is a bottom-up perspective view of the composite airfoil assembly of FIG. **2**, further illustrating a gap formed between opposing ends of the wrap.
[0012] FIG. **7** is a top-down cross-sectional view of an exemplary airfoil assembly suitable for use

as the composite airfoil assembly of FIG. **2**, further illustrating a wrap including a first body and a second body.

[0013] FIG. **8** is a top-down cross-sectional view of an exemplary airfoil assembly suitable for use as the composite airfoil assembly of FIG. **2**, further illustrating a wrap including a continuous body.

[0014] FIG. **9** is a schematic cross-sectional view of a portion of an exemplary airfoil assembly suitable for use as the composite airfoil assembly of FIG. **2**, further comprising a composite airfoil with a composite skin, and a wrap provided over a respective portion of the composite skin.

[0015] FIG. **10** is a schematic cross-sectional view of a portion of an exemplary airfoil assembly suitable for use as the composite airfoil assembly of FIG. **2**, further comprising a wrap and a second wrap.

DETAILED DESCRIPTION

[0016] Aspects of the disclosure herein are directed to a composite airfoil assembly for a turbine engine. The composite airfoil assembly includes a composite airfoil, a spar, a trunnion, and a wrap. The spar includes a stem and a base extending from the stem. The spar includes a transition extending between the stem and the base. The wrap at least partially encircles the transition. The wrap can be used to strengthen the composite airfoil assembly along the transition.

[0017] For purposes of illustration, the present disclosure will be described with respect to a composite airfoil assembly for a turbine engine, specifically a fan blade of the turbine engine. It will be understood, however, that aspects of the disclosure described herein are not so limited and can have general applicability within other engines or within other portions of the turbine engine. For example, the disclosure can have applicability for a composite airfoil assembly in other engines or vehicles, and can be used to provide benefits in industrial, commercial, and residential applications.

[0018] As used herein, the term “upstream” refers to a direction that is opposite the fluid flow direction, and the term “downstream” refers to a direction that is in the same direction as the fluid flow. The term “fore” or “forward” means in front of something and “aft” or “rearward” means behind something. For example, when used in terms of fluid flow, fore/forward can mean upstream and aft/rearward can mean downstream.

[0019] Additionally, as used herein, the terms “axial” and “longitudinal” both refer to a direction parallel to a centerline axis of an object, while the terms “radial” or “radially” refer to a direction that is perpendicular to the axial direction or away from a common center. For example, in the overall context of a turbine engine, radial refers to a direction along a ray extending between a center longitudinal axis of the engine and an outer engine circumference. Furthermore, as used herein, the term “set” or a “set” of elements can be any number of elements, including only one.

[0020] Further, as used herein, the term “fluid” or iterations thereof can refer to any suitable fluid within the gas turbine engine at least a portion of the gas turbine engine is exposed to such as, but not limited to, combustion gases, ambient air, pressurized airflow, working airflow, or any combination thereof. It is yet further contemplated that the gas turbine engine can be another suitable turbine engine such as, but not limited to, a steam turbine engine or a supercritical carbon dioxide turbine engine. As a non-limiting example, the term “fluid” can refer to steam in a steam turbine engine, or to carbon dioxide in a supercritical carbon dioxide turbine engine.

[0021] All directional references (e.g., radial, axial, proximal, distal, upper, lower, upward, downward, left, right, lateral, front, back, top, bottom, above, below, vertical, horizontal, clockwise, counterclockwise, upstream, downstream, forward, aft, etc.) are only used for identification purposes to aid the reader's understanding of the present disclosure, and do not create limitations, particularly as to the position, orientation, or use of aspects of the disclosure described herein. Connection references (e.g., attached, coupled, secured, fastened, connected, and joined) are to be construed broadly and can include intermediate members between a collection of elements and relative movement between elements unless otherwise indicated. As such, connection references do not necessarily infer that two elements are directly connected and in fixed relation to one another. The exemplary drawings are for purposes of illustration only and the dimensions, positions, order and relative sizes reflected in the drawings attached hereto can vary.

[0022] The term “composite,” as used herein is, is indicative of a component having two or more materials. A composite can be a combination of at least two or more metallic, non-metallic, or a combination of metallic and non-metallic elements or materials. Examples of a composite material can be, but are not limited to, a polymer matrix composite (PMC), a ceramic matrix composite (CMC), a metal matrix composite (MMC), carbon fibers, a polymeric resin, a thermoplastic resin, bismaleimide (BMI) materials, polyimide materials, an epoxy resin, glass fibers, and silicon matrix materials.

[0023] As used herein, a “composite” component refers to a structure or a component including any suitable composite material. Composite components, such as a composite airfoil, can include several layers or plies of composite material. The layers or plies can vary in stiffness, material, and dimension to achieve the desired composite component or composite portion of a component having a predetermined weight, size, stiffness, and strength.

[0024] One or more layers of adhesive can be used in forming or coupling composite components. Adhesives can include resin and phenolics, wherein the adhesive can require curing at elevated temperatures or other hardening techniques.

[0025] As used herein, PMC refers to a class of materials. By way of example, the PMC material is defined in part by a prepreg, which is a reinforcement material pre-impregnated with a polymer matrix material, such as thermoplastic resin. Non-limiting examples of processes for producing thermoplastic prepregs include hot melt pre-pregging in which the fiber reinforcement material is drawn through a molten bath of resin and powder pre-pregging in which a resin is deposited onto the fiber reinforcement material, by way of non-limiting example electrostatically, and then adhered to the fiber, by way of non-limiting example, in an oven or with the assistance of heated rollers. The prepregs can be in the form of unidirectional tapes or woven fabrics, which are then stacked on top of one another to create the number of stacked plies desired for the part.

[0026] Multiple layers of prepreg are stacked to the proper thickness and orientation for the composite component and then the resin is cured and solidified to render a fiber reinforced composite part. Resins for matrix materials of PMCs can be generally classified as thermosets or thermoplastics. Thermoplastic resins are generally categorized as polymers that can be repeatedly softened and flowed when heated and hardened when sufficiently cooled due to physical rather than chemical changes. Notable example classes of thermoplastic resins include nylons, thermoplastic polyesters, polyaryletherketones, and polycarbonate resins. Specific example of high performance thermoplastic resins that have been contemplated for use in aerospace applications include, polyetheretherketone (PEEK), polyetherketoneketone (PEKK), polyetherimide (PEI), polyaryletherketone (PAEK), and polyphenylene sulfide (PPS). In contrast, once fully cured into a hard rigid solid, thermoset resins do not undergo significant softening when heated, but instead thermally decompose when sufficiently heated. Notable examples of thermoset resins include epoxy, bismaleimide (BMI), and polyimide resins.

[0027] Instead of using a prepreg, in another non-limiting example, with the use of thermoplastic polymers, it is possible to utilize a woven fabric. Woven fabric can include, but is not limited to, dry carbon fibers woven together with thermoplastic polymer fibers or filaments. Non-prepreg braided architectures can be made in a similar fashion. With this approach, it is possible to tailor the fiber volume of the part by dictating the relative concentrations of the thermoplastic fibers and reinforcement fibers that have been woven or braided together. Additionally, different types of reinforcement fibers can be braided or woven together in various concentrations to tailor the properties of the part. For example, glass fibers, carbon fibers, and thermoplastic fibers could all be woven together in various concentrations to tailor the properties of the part. The carbon fibers provide the strength of the system, the glass fibers can be incorporated to enhance the impact properties, which is a design characteristic for parts located near the inlet of the engine, and the thermoplastic fibers provide the binding for the reinforcement fibers.

[0028] In yet another non-limiting example, resin transfer molding (RTM) can be used to form at least a portion of a composite component. Generally, RTM includes the application of dry fibers or matrix material to a mold or cavity. The dry fibers or matrix material can include prepreg, braided material, woven material, or any combination thereof.

[0029] Resin can be pumped into or otherwise provided to the mold or cavity to impregnate the dry fibers or matrix material. The combination of the impregnated fibers or matrix material and the resin are then cured and removed from the mold. When removed from the mold, the composite component can require post-curing processing.

[0030] It is contemplated that RTM can be a vacuum assisted process. That is, the air from the cavity or mold can be removed and replaced by the resin prior to heating or curing. It is further contemplated that the placement of the dry fibers or matrix material can be manual or automated. As a non-limiting example, the placement of dry fibers or matrix material can be done through automatic fiber placement (AFP) or manually by hand.

[0031] The dry fibers or matrix material can be contoured to shape the composite component or direct the resin. Optionally, additional layers or reinforcing layers of a material differing from the dry fiber or matrix material can also be included or added prior to heating or curing.

[0032] As used herein, CMC refers to a class of materials with reinforcing fibers in a ceramic matrix. Generally, the reinforcing fibers provide structural integrity to the ceramic matrix. Some examples of reinforcing fibers can include, but are not limited to, non-oxide silicon-based materials (e.g., silicon carbide, silicon nitride, or mixtures thereof), non-oxide carbon-based materials (e.g., carbon), oxide ceramics (e.g., silicon oxycarbides, silicon oxynitrides, aluminum oxide (Al.sub.2O.sub.3), silicon dioxide (SiO.sub.2), aluminosilicates such as mullite, or mixtures thereof), or mixtures thereof.

[0033] Some examples of ceramic matrix materials can include, but are not limited to, non-oxide silicon-based materials (e.g., silicon carbide, silicon nitride, or mixtures thereof), oxide ceramics (e.g., silicon oxycarbides, silicon oxynitrides, aluminum oxide (Al.sub.2O.sub.3), silicon dioxide (SiO.sub.2), aluminosilicates, or mixtures thereof), or mixtures thereof. Optionally, ceramic particles (e.g., oxides of Si, Al, Zr, Y, and combinations thereof) and inorganic fillers (e.g., pyrophyllite, wollastonite, mica, talc, kyanite, and montmorillonite) can also be included within the ceramic matrix.

[0034] Generally, particular CMCs can be referred to as their combination of type of fiber/type of matrix. For example, C/SiC for carbon-fiber-reinforced silicon carbide; SiC/SiC for silicon carbide-fiber-reinforced silicon carbide, SiC/SiN for silicon carbide fiber-reinforced silicon nitride; SiC/SiC—SiN for silicon carbide fiber-reinforced silicon carbide/silicon nitride matrix mixture, etc. In other examples, the CMCs can be comprised of a matrix and reinforcing fibers comprising oxide-based materials such as aluminum oxide (Al.sub.2O.sub.3), silicon dioxide (SiO.sub.2), aluminosilicates, and mixtures thereof. Aluminosilicates can include crystalline materials such as mullite (3Al.sub.2O.sub.3.Math.2SiO.sub.2), as well as glassy aluminosilicates.

[0035] In certain non-limiting examples, the reinforcing fibers may be bundled and/or coated prior to inclusion within the matrix. For example, bundles of the fibers may be formed as a reinforced tape, such as a unidirectional reinforced tape. A plurality of the tapes may be laid up together to form a preform component. The bundles of fibers may be impregnated with a slurry composition prior to forming the preform or after formation of the preform. The preform may then undergo thermal processing, and subsequent chemical processing to arrive at a component formed of a CMC material having a desired chemical composition. For example, the preform may undergo a cure or burn-out to yield a high char residue in the preform, and subsequent melt-infiltration with silicon, or a cure or pyrolysis to yield a silicon carbide matrix in the preform, and subsequent chemical vapor infiltration with silicon carbide. Additional steps may be taken to improve densification of the preform, either before or after chemical vapor infiltration, by injecting it with a liquid resin or polymer followed by a thermal processing step to fill the voids with silicon carbide. CMC material as used herein may be formed using any known or hereinafter developed methods including but not limited to melt infiltration, chemical vapor infiltration, polymer impregnation pyrolysis (PIP), or any combination thereof.

[0036] Such materials, along with certain monolithic ceramics (i.e., ceramic materials without a reinforcing material), are particularly suitable for higher temperature applications. Additionally, these ceramic materials are lightweight compared to superalloys, yet can still provide strength and durability to the component made therefrom. Therefore, such materials are currently being considered for many gas turbine components used in higher temperature sections of gas turbine engines, such as airfoils (e.g., turbines, and vanes), combustors, shrouds and other like components, that would benefit from the lighter-weight and higher temperature capability these materials can offer.

[0037] The term “metallic” as used herein is indicative of a material that includes metal such as, but not limited to, titanium, iron, aluminum, stainless steel, and nickel alloys. A metallic material or alloy can be a combination of at least two or more elements or materials, where at least one is a metal.

[0038] FIG. **1** is a schematic cross-sectional diagram of a turbine engine, specifically an open rotor or unducted turbine engine **10** for an aircraft. The unducted turbine engine **10** has a generally longitudinally extending axis or engine centerline **12** extending from a forward end **14** to an aft end **16**. The unducted turbine engine **10** includes, in downstream serial flow relationship, a set of circumferentially spaced blades or propellers defining a fan section **18** including a fan **20**, a compressor section **22** including a booster or low pressure (LP) compressor **24** and a high pressure (HP) compressor **26**, a combustion section **28** including a combustor **30**, a turbine section **32** including an HP turbine **34**, and an LP turbine **36**, and an exhaust section **38**. The unducted turbine engine **10** as described herein is meant as a non-limiting example, and other architectures are possible, such as, but not limited to, a steam turbine engine, a supercritical carbon dioxide turbine engine, or any other suitable turbine engine.

[0039] An exterior surface, defined by a housing or nacelle **40**, of the unducted turbine engine **10** extends from the forward end **14** of the unducted turbine engine **10** toward the aft end **16** of the unducted turbine engine **10** and covers at least a portion of the compressor section **22**, the combustion section **28**, the turbine section **32**, and the exhaust section **38**. The fan section **18** can be positioned at a forward portion of the nacelle **40** and extend radially outward from the nacelle **40** of the unducted turbine engine **10**. Specifically, the fan section **18** extends radially outward from the nacelle **40**. The fan section **18** includes a set of fan blades **42**, and a set of stationary fan vanes **82** downstream the set of fan blades **42**, both disposed radially from and circumferentially about the engine centerline **12**. The set of fan blades **42** and the set of stationary fan vanes **82** extend radially outward from respective portions of the nacelle **40**. As such, the set of fan blades **42** and the set of stationary fan vanes **82** can be defined as an exterior set of fan blades and an exterior set of stationary fan vanes **82**, respectively. The unducted turbine engine **10** includes any number of one or more sets of rotating blades or propellers (e.g., the set of fan blades **42**) disposed upstream of the set of stationary fan vanes **82**. As a non-limiting example, the unducted turbine engine **10** can include multiple sets of fan blades **42** or stationary fan vanes **82**. As such, the unducted turbine engine **10** is further defined as an unducted single-fan turbine engine. The unducted turbine engine **10** is further defined by the location of the fan section **18** with respect to the combustion section **28**. The fan section **18** can be upstream, downstream, or in-line with the axial positioning of the combustion section **28**.

[0040] The compressor section **22**, the combustion section **28**, and the turbine section **32** are collectively referred to as an engine core **44**, which generates combustion gases. The engine core **44** is surrounded by an engine casing **46**, which is operatively coupled with a portion of the nacelle **40** of the unducted turbine engine **10**.

[0041] An HP shaft or spool **48** disposed coaxially about the engine centerline **12** of the unducted turbine engine **10** drivingly connects the HP turbine **34** to the HP compressor **26**. An LP shaft or spool **50**, which is disposed coaxially about the engine centerline **12** of the unducted turbine engine **10** within the larger diameter annular HP spool **48**, drivingly connects the LP turbine **36** to the LP compressor **24** and fan **20**. The spools **48**, **50** are rotatable about the engine centerline **12** and coupled to a set of rotatable elements, which collectively define a rotor **51**.
[0042] It will be appreciated that the unducted turbine engine **10** is either a direct drive or integral drive engine utilizing a reduction gearbox coupling the LP shaft or spool **50** to the fan **20**.
[0043] The LP compressor **24** and the HP compressor **26**, respectively, include a set of compressor stages **52**, **54**, in which a set of compressor blades **56**, **58** rotate relative to a corresponding set of static compressor vanes **60**, **62** (also called a nozzle) to compress or pressurize the stream of fluid passing through the stage. In a single compressor stage **52**, **54**, multiple compressor blades **56**, **58** are provided in a ring and extend radially outwardly relative to the engine centerline **12**, from a blade platform to a blade tip, while the corresponding static compressor vanes **60**, **62** are positioned upstream of and adjacent to the compressor blades **56**, **58**. It is noted that the number of blades, vanes, and compressor stages shown in FIG. **1** were selected for illustrative purposes only, and that other numbers are possible.
[0044] The compressor blades **56**, **58** for a stage of the compressor section **22** are mounted to a disk **61**, which is mounted to the corresponding one of the HP and LP spools **48**, **50**, with each stage having its own disk **61**. The static compressor vanes **60**, **62** for a stage of the compressor section **22** are mounted to the engine casing **46** in a circumferential arrangement.
[0045] The HP turbine **34** and the LP turbine **36**, respectively, include a set of turbine stages **64**, **66**, in which a set of turbine blades **68**, **70** are rotated relative to a corresponding set of static turbine vanes **72**, **74** (also called a nozzle) to extract energy from the stream of fluid passing through the stage. In a single turbine stage **64**, **66**, multiple turbine blades **68**, **70** are provided in a ring and extends radially outwardly relative to the engine centerline **12**, from a blade platform to a blade tip, while the corresponding static turbine vanes **72**, **74** are positioned upstream of and adjacent to the turbine blades **68**, **70**. It is noted that the number of blades, vanes, and turbine stages shown in FIG. **1** were selected for illustrative purposes only, and that other numbers are possible.
[0046] The turbine blades **68**, **70** for a stage of the turbine section **32** are mounted to a disk **71**, which is mounted to the corresponding one of the HP and LP spools **48**, **50**, with each stage having a dedicated disk **71**. The static turbine vanes **72**, **74** for a stage of the turbine section **32** are mounted to the engine casing **46** in a circumferential arrangement.
[0047] Rotary portions of the unducted turbine engine **10**, such as the blades **56**, **58** **68**, **70** among the compressor section **22** and the turbine section **32** are also referred to individually or collectively as the rotor **51**. As such, the rotor **51** refers to the combination of rotating elements throughout the unducted turbine engine **10**.
[0048] Complementary to the rotary portions, the stationary portions of the unducted turbine engine **10**, such as the static vanes **60**, **62**, **72**, **74** among the compressor section **22** and the turbine section **32** are also referred to individually or collectively as a stator **63**. As such, the stator **63** refers to the combination of non-rotating elements throughout the unducted turbine engine **10**.
[0049] The nacelle **40** is operatively coupled to the unducted turbine engine **10** and covers at least a portion of the engine core **44**, the engine casing **46**, or the exhaust section **38**. At least a portion of the nacelle **40** extends axially forward or upstream the illustrated position. For example, the nacelle **40** extends axially forward such that a portion of the nacelle **40** overlays or covers a portion of the fan section **18** or a booster section (not illustrated) of the unducted turbine engine **10**. The turbine engine includes a pylon **84**. The pylon **84** mounts the turbine engine **10** to an exterior structure (e.g., a fuselage of an aircraft, a wing, a tail wing, etc.).
[0050] It will be appreciated that the unducted turbine engine **10** can be split into at last two separate portions; a rotor portion and a stator portion. The rotor portion can be defined as any

portion of the unducted turbine engine **10** that rotates about a respective rotational axis. the stator portion can be defined by a combination of non-rotating elements provided within the unducted turbine engine **10**. As a non-limiting example, the rotor portion can include the plurality of fan blades **42**, the compressor blades **56**, **58**, or the turbine blades **68**, **70**. As a non-limiting example, the stator portion can include the plurality of fan vanes **82**, the static compressor vanes **60**, **62**, or the static turbine vanes **72**, **74**.

[0051] During operation of the unducted turbine engine **10**, a freestream airflow **80** flows against a forward portion of the unducted turbine engine **10**. A first portion of the freestream airflow **80** flows along the nacelle **40** and over the set of stationary fan vanes **82** as an exterior airflow **78**. The exterior airflow **78** flows past the set of stationary fan vanes **82**, following the curvature of the nacelle **40** and toward the exhaust section **38**. A second portion of the freestream airflow **80** enters an annular area **25** defined by a swept area between an outer surface of the nacelle **40** and the tip of the fan blade **42**, with this air flow being an inlet airflow **76**. A portion of the inlet airflow **76** enters the engine core **44** and is described as an inlet airflow **76**, which is used for combustion within the engine core **44**.

[0052] More specifically, the working airflow **76** flows into the LP compressor **24**, which then pressurizes the working airflow **76** thus defining a pressurized airflow that is supplied to the HP compressor **26**, which further pressurizes the air. The working airflow **76**, or the pressurized airflow, from the HP compressor **26** is mixed with fuel in the combustor **30** and ignited, thereby generating combustion gases. Some work is extracted from these gases by the HP turbine **34**, which drives the HP compressor **26**. The combustion gases are discharged into the LP turbine **36**, which extracts additional work to drive the LP compressor **24**, and the working airflow **76**, or exhaust gas, is ultimately discharged from the unducted turbine engine **10** via the exhaust section **38**. The driving of the LP turbine **36** drives the LP spool **50** to rotate the fan **20** and the LP compressor **24**. The working airflow **76**, including the pressurized airflow and the combustion gases, defines a working airflow that flows through the compressor section **22**, the combustion section **28**, and the turbine section **32** of the unducted turbine engine **10**.

[0053] The working airflow **76** and at least some of the exterior airflow **78** merge downstream of the exhaust section **38** of the unducted turbine engine **10**. The working airflow **76** and the exterior airflow **78**, together, form an overall thrust of the unducted turbine engine **10**.

[0054] It is contemplated that a portion of the working airflow **76** is drawn as bleed air **77** (e.g., from the compressor section **22**). The bleed air **77** provides an airflow to engine components requiring cooling. The temperature of the working airflow **76** exiting the combustor **30** is significantly increased with respect to the working airflow **76** within the compressor section **22**. As such, cooling provided by the bleed air **77** is necessary for operating of such engine components in the heightened temperature environments or a hot portion of the unducted turbine engine **10**. In the context of a turbine engine, the hot portions of the engine are normally downstream of the combustor **30**, especially the turbine section **32**, with the HP turbine **34** being the hottest portion as it is directly downstream of the combustion section **28**. Other sources of cooling fluid are, but are not limited to, fluid discharged from the LP compressor **24** or the HP compressor **26**.

[0055] FIG. **2** is schematic illustration of a composite airfoil assembly **130** suitable for use within the unducted turbine engine **10** of FIG. **1**. The composite airfoil assembly **130** includes a composite airfoil **132** that is any suitable airfoil of the turbine engine **10**. The composite airfoil assembly **130** can be provided within the rotor portion or stator portion of the unducted turbine engine **10**. As a non-limiting example, the composite airfoil **132** can be a blade of the plurality of fan blades **42**, or a blade from the compressor blades **56**, **58** or the turbine blades **68**, **70**. In the instance where the composite airfoil **132** is a blade, the composite airfoil assembly **130** can be provided within the rotor portion of the turbine engine **10**. It is contemplated that the composite airfoil **132** can be a blade, vane, airfoil, or other component of any turbine engine, such as, but not limited to, a gas turbine engine, a turboprop engine, a turboshaft engine, a ducted turbofan engine, the unducted turbine engine **10**, or an open rotor turbine engine.

[0056] The composite airfoil **132** includes an outer wall **138** bounding an interior **148**. The outer wall **138** extends between a leading edge **144** and a trailing edge **146** to define a chordwise direction (C). The outer wall **138** further extends between a root **140** and a tip **142** to define a spanwise direction(S). The outer wall **138** can be a composite wall made of one or more layers of composite material. The one or more layers of material can be applied during the same stage or different stages of the manufacturing of the composite airfoil **132**.

[0057] At least a portion of the composite airfoil **132** can include a composite material. By way of non-limiting example, the outer wall **138**, the spar **136**, or a combination thereof can include at least a PMC portion, a polymeric portion, or both. The PMC portion can include, but is not limited to, a matrix of thermoset (epoxies, phenolics) or thermoplastic (polycarbonate, polyvinylchloride, nylon, acrylics) and embedded glass, carbon, steel, or a combination thereof. It will be appreciated that the composite airfoil **132** can include a composite material, a non-composite metallic material, any other suitable material, or a combination thereof.

[0058] The composite airfoil assembly **130** includes a spar **136** and a trunnion **134**. The spar **136** extends into the interior **148** and it coupled to the airfoil **132** through any suitable method. The spar **136** extends from the root **140**. The spar **136** is operably coupled to the trunnion **134** (e.g., bonding, adhesion, fastening, or any other suitable coupling method). The trunnion **134** includes any suitable material such as, but not limited to, a metallic material or a composite material. It will be appreciated that the term composite material can further include metals with a composite architecture (e.g., a metal matrix composite). In the case of a composite material, the trunnion **134** can be any suitable composite material such as a **2**D or **3**D composite, a laminate composite skin, a woven or braided composite, or any other suitable composite.

[0059] The composite airfoil **132** has a span length (L) measured along the spanwise direction(S) from the root **140** at 0% the span length (L) to the tip **142** at 100% the span length (L). An entirety of the spar **136** can be located below 20% of the span length (L). Alternatively, the spar **136** can extend past 20% of the span length (L).

[0060] The composite airfoil assembly **130** includes a wrap **150** provided along a respective portion of at least the spar **136**. The wrap **150** includes any suitable material. As a non-limiting example, the wrap **150** can include a composite material such that the wrap **150** is a composite wrap. As a non-limiting example, the wrap **150** can include a metallic material such that the wrap **150** is a metallic wrap.

[0061] The wrap **150** can be formed by a single layer of material or a plurality of materials, such as a plurality of stacked materials. As a non-limiting example, the wrap **150** can include a metallic material that defines a single layer of material provided along the composite airfoil assembly **130**. As a non-limiting example, the wrap **150** can include a composite material that is wrapped around a respective portion of the composite airfoil assembly **130** multiple times to define a plurality of stacked composite layers.

[0062] During operation of the composite airfoil assembly **130**, the trunnion **134** can rotate about a pitch axis (Pax) in a rotational direction (Rd). As the spar **136** couples the trunnion **134** to the composite airfoil **132**, rotation of the trunnion **134** in the rotational direction (Rd) causes the composite airfoil **132** to rotate about the pitch axis (Pax). This rotation can be used to control the pitch of the composite airfoil assembly **130** such that the composite airfoil assembly **130** is defined as a composite variable pitch airfoil assembly. The pitch of the composite airfoil assembly **130** can be varied based on the operation or intended operation of the turbine engine (e.g., the turbine engine **10** of FIG. **1**) that the composite airfoil assembly **130** is provided on. A working airflow (Fw) flows over a respective portion of the composite airfoil assembly **130**, specifically, the composite airfoil **132**.

[0063] FIG. **3** is a schematic cross-sectional view of a portion of the composite airfoil assembly **130** as seen from sectional line III-III of FIG. **2**. The spar **136** includes a spar centerline axis **164**.

The spar **136** includes a stem **158** and a base **160** interconnected by a transition **162**. The base **160** extends into a respective portion of the trunnion **134**. The stem **158** extends into the interior **148** (FIG. **2**) of the composite airfoil **132**. The stem **158** and the base **160** are defined with respect to the airfoil **132**. As a non-limiting example, a majority of the stem **158** is provided within the interior **148**, while a majority of the base **160** is provided exterior the interior **148**.

[0064] The composite airfoil **132** includes a composite skin **152**. The composite skin **152** defines any suitable portion of the composite airfoil **132**. As a non-limiting example, the composite skin **152** can define at least a portion of the outer wall **138** (FIG. **2**) of the composite airfoil **132**. The composite airfoil **132** includes a suction side **15** and an opposing pressure side **156**.

[0065] The trunnion **134** includes an inner surface **166** defining a socket **168**. The socket **168** can include a cross-sectional area when viewed along a plane extending along the spar centerline axis **164**. The cross-sectional area of the socket **168** can be any suitable shape such as, but not limited to, rectangular, flared, curved, or a combination thereof. The trunnion **134** includes an upper edge **170** that opposes the root **140** of the composite airfoil **132**. The upper edge **170** is spaced from the root **140**. The upper edge **170** includes an open top **172** opening to the socket **168**. The base **160** of the spar **136** extends through the open top **172** and into the socket **168**.

[0066] The transition **162** defines an area interconnecting the stem **158** and the base **160**. The stem **158**, the base **160**, and the transition **162** are each defined by respective cross-sectional areas when viewed along a plane extending along the spar centerline axis **164**. The stem **158**, the transition **162**, and the base **160** can each include a constant or non-constant cross-sectional area. As a non-limiting example, the stem **158** can have a smaller radial width with respect to the base **160**. The transition **162** can be formed as a tapered section that interconnects the stem **158** and the base **160** such that the transition **162** includes a non-constant cross-sectional area extending constantly or non-constantly from the radial width of the stem **158** at the transition **162** to the radial width of the base **160** at the transition **162**.

[0067] The transition **162** can extend any suitable axial distance along the spar centerline axis **164**. As a non-limiting example, the transition **162** can be denoted by a planar region of where the stem **158** meets the base **160**. As a non-limiting example, the stem **158** and the spar **136** can have a constant cross-sectional area. As such, the transition **162** can be defined as a planar region where the spar **136** exits the airfoil **132**. Put another way, the stem **158** can be a portion of the spar **136** provided entirely within the airfoil **132**, while the base **160** can be a portion of the spar **136** provided entirely outside of the airfoil **132**.

[0068] The wrap **150** is provided along and radially overlay a respective portion of the spar **136**. As a non-limiting example, the wrap **150** encircles or otherwise circumferentially surrounds at least a portion of the transition **162**. As a non-limiting example, the wrap **150** can fully or partially encircle the transition **162**. The wrap **150** extends axially along the composite airfoil assembly **130** any suitable distance. As a non-limiting example, the wrap **150** can extend axially along the base **160** of the spar **136** and terminate axially at the transition **162**. Alternatively, the wrap **150** can extend axially beyond the transition **162** and axially over at least a portion of the stem **158** or the composite skin **152**. As a non-limiting example, the wrap **150** can terminate axially prior to the upper edge **170**. As a non-limiting example, the wrap **150** can terminate axially at the upper edge **170**.

[0069] The wrap **150** is coupled to the spar **136** through any suitable method. As a non-limiting example, the wrap **150** can be press-fit over the spar **136** and held in frictional contact with the spar **136**. As a non-limiting example, the wrap **150** can be wrapped around itself and held in frictional contact with the spar **136**. As a non-limiting example, the wrap **150** can be coupled to the spar **136** or any other suitable portion of the composite airfoil assembly **130** through any suitable method such as, but not limited to, adhesion, fastening, welding, frictional contact, integral formation, bonding, curing, or a combination thereof.

[0070] FIG. **4** is a schematic cross-sectional view of the wrap **150** of FIG. **3** when viewed along a plane extending along the spar centerline axis **164** (FIG. **3**) and intersecting the wrap **150**. The wrap **150** includes a first region **182** and a second region **184** on either side of the first region **182**. The first region **182** defines a central region of the wrap **150** while the second region **184** defines edges of the wrap **150**. For purposes of illustration, a transition between the first region **182** and the second region **184** has been shown in phantom lines **185**.

[0071] The wrap **150** includes an outer surface **174**, an inner surface **176**, and a perimeter surface **178**. The inner surface **176** confronts a respective portion of the composite airfoil assembly **130** (e.g., the spar **136**). The perimeter surface **178** defines a perimeter of the wrap **150**. The wrap **150** includes a connecting surface **186** interconnecting the outer surface **174** and the perimeter surface **178**. The outer surface **174**, the inner surface **176**, the perimeter surface **178**, and the connecting surface **186** is formed in any suitable manner, such as, but not limited to, a linear surface, a non-linear surface, or a combination thereof. As a non-limiting example, the connecting surface **186** can be rounded.

[0072] The connecting surface **186** extends inwardly from the first region **182** and to the perimeter surface **178**. In other words, the connecting surface **186**, and thus the second region **184** is defined by a tapered or fileted region of the wrap **150**.

[0073] The wrap **150** is defined by a series of thicknesses between the inner surface **176** and outer surface **174** or connecting surface **186**. The wrap **150** includes a first thickness (T**1**), and a second thickness (T**2**). The first thickness (T**1**) is defined as a thickness of the first region **182**. The second thickness (T**2**) is defined as a thickness of the second region **184**. The second thickness (T**2**) can be provided at a respective portion of the perimeter surface **178**. The first region **182** can include a constant thickness such that the first thickness (T**1**) defines a maximum thickness of an entirety of the wrap **150**. The first thickness (T**1**) is larger than the second thickness (T**2**).

[0074] The first thickness (T**1**) and the second thickness (T**2**) are any suitable size. As a non-limiting example, the first thickness (T**1**) and the second thickness (T**2**) are greater than or equal to 0.01 inches and less than or equal to 0.2 inches. As a non-limiting example, the first thickness (T**1**) and the second thickness (T**2**) are greater than or equal to 0.04 inches and less than or equal to 0.2 inches.

[0075] FIG. **5** is schematic view of the wrap **150** of FIG. **3** as seen along a plane extending circumferentially with respect to the spar centerline axis **164** (FIG. **3**). The wrap **150** has been splayed out and flattened for illustrative purposes only. The illustrated view is of a top-down view of the wrap **150** along the outer surface **174** of the wrap. The second region **184** extends continuously along the wrap **150** such that the first region **182** is surrounded or encompassed by the second region **184**.

[0076] As illustrated, the second region **184** extends continuously about an entirety of the first region **182** and defines an entirety of the perimeter surface **178**. It will be appreciated, however, that at least a portion of the first region **182** can extend to the perimeter surface **178**. As a non-limiting example, the second region **184** can be provided on opposing sides of the wrap **150**.

[0077] The wrap **150** can include a rectangular surface area when viewed as illustrated from a top-down perspective. It will be appreciated that the wrap **150** can include any suitable shaped surface area such as, but not limited to, a rectangular surface area, a trapezoidal surface area, a triangular surface area, a circular surface area, an ovular surface area, a hexagonal surface area, or the like.

[0078] FIG. **6** is a bottom-up perspective view of the composite airfoil assembly **130** of FIG. **2**. The airfoil **132** includes the root **140**. The airfoil **132** includes the suction side **156** and the pressure side **156**. The outer surface **174** of the wrap **150** defines a radially outer portion of the wrap **150**. The wrap **150** contacts or is spaced from the root **140** of the airfoil **132**.

[0079] The wrap **150** extends circumferentially about an entirety of or less than an entirety of the spar centerline axis **164**. As a non-limiting example, at least a portion of the perimeter surface **178** of the wrap **150** can be circumferentially spaced from a circumferentially opposing portion of the perimeter surface **178** to define a gap (G) therebetween. The gap (G) is any suitable size. As a non-limiting example, the gap (G) could be zero such that circumferentially opposing ends of the wrap **150** touch.

[0080] A size of the gap (G) is selected based on, at least partially, the manufacture of the composite airfoil assembly **130**. As a non-limiting example, the wrap **150** can be flattened (as illustrated in FIG. **5**) prior to being coupled to the spar **136**. The wrap **150** can then be bent or otherwise wrapped around a respective portion of the spar **136**. It is contemplated that the larger the gap (G), the less distance that the wrap **150** needs to be bent. As such, providing a larger gap (G) decreases the burden of coupling the wrap **150** to the spar **136**. As a non-limiting example, the wrap **150** includes a metallic material. The wrap **150** can be heated to increase the mouldability of the wrap **150**. The heated wrap **150** can then be press-fit around a respective portion of the composite airfoil assembly **130** and subsequently coupled to the composite airfoil assembly **130** through any suitable coupling method such as, but not limited to, welding, adhesion, friction, boning, fastening, or the like.

[0081] The wrap **150** can have any suitable construction. As a non-limiting example, the connecting surface **186** can extend about less than an entirety of the total perimeter surface **178**. As a non-limiting example, the connecting surface **186**, or tapered surface, can be provided on axially opposing sides of the wrap **150**, with respect to the spar centerline axis **164**, and the first region **182** can extend to the perimeter surface **178** on circumferentially opposing ends of the wrap **150**. As a non-limiting example, the connecting surface **186** can be omitted from the circumferentially opposing ends of the wrap **150** when the gap (G) is zero such that the circumferentially opposing ends touch.

[0082] During operation of the composite airfoil assembly **130**, a working airflow (Fw) flows over the composite airfoil **132** from the leading edge **144** and to the trailing edge **146**. As the working airflow (Fw) flows over the composite airfoil **132**, the composite airfoil extracts a work from the working airflow (Fw). As a non-limiting example, the composite airfoil assembly **130** can be provided within the fan section **18** (FIG. **1**), and the composite airfoil **132** can be used to direct the working airflow into a respective portion of the turbine engine **10** (FIG. **1**). The composite airfoil **132** can further rotate in an operational rotational direction (Dr). Alternatively, the composite airfoil **132** can be static.

[0083] It is contemplated that during operation of the composite airfoil assembly **130**, at least one of the working airflow (Fw), the rotation of the composite airfoil **132** in the operational rotational direction (Dr), or a combination thereof, transfers or induces a force to the composite airfoil **132**. As a non-limiting example, the working airflow (Fw) can transfer a force in-line with the direction of the working airflow (Fw) to the composite airfoil **132**. As a non-limiting example, the rotation of the composite airfoil **132** in the operational rotational direction (Dr) causes a force opposite the operational rotational direction (Dr) to be experienced along the composite airfoil **132** due to the drag of the composite airfoil **132**. The forces experienced along the composite airfoil **132** during operation of the composite airfoil assembly **130** will hereinafter be referred to as the operational forces. The operational forces can further include any other suitable force, such as, but not limited to, external forces applied to the composite airfoil assembly **130**.

[0084] The operational forces along the composite airfoil **132** are transferred from the composite airfoil **132** and to the spar **136**. It is contemplated that the spar **136** will experience the largest forces at the transition **162** (FIG. **3**). The wrap **150** is used to strengthen the composite airfoil assembly **130** at the transition **162** where the highest operational forces along the spar **136** are experienced.

[0085] The material of the wrap **150**, the size of the wrap **150**, the orientation of the wrap **150**, or a combination thereof is used to strengthen the composite airfoil assembly **130** against the operational force. As a non-limiting example, the wrap **150** can be metallic and therefore be more resilient to the operational forces than the composite ceramic material of the spar **136**. It is contemplated that the construction of the wrap **150** can result in a wrap **150** being better adapted to strengthen the spar **136** against the operational forces. As a non-limiting example, forming the wrap **150** with a tapered section (e.g., the second region **184**) helps with transferring the operational forces from the spar **136** and to the wrap **150**. Specifically, the connecting surface **186** creates a smoother transition between the wrap **150** and the spar **136**, as opposed to the wrap **150** being formed without the connecting surface **186**. The smooth transition between the wrap **150** and the spar **136**, in turn, reduces potential edge of contact stresses between the wrap **150** and the spar **136**. The wrap **150** further provides for a load transition from the composite skin **152** and to the spar **136**. The wrap **150** helps distribute loads between the composite skin **152** and the spar **136**.

[0086] FIG. **7** is a top-down cross-sectional view of an exemplary airfoil assembly **230** suitable for use as the composite airfoil assembly **130** of FIG. **2**. The composite airfoil assembly **230** is similar to the composite airfoil assembly **130**; therefore, like parts will be identified with like numerals increased to the **230** series with it being understood that the description of the composite airfoil assembly **130** applies to the composite airfoil assembly **230** unless indicated otherwise.

[0087] The composite airfoil assembly **230** includes a spar **236**. The spar **236** has a spar centerline axis **264**. The composite airfoil assembly **230** incudes a wrap **250**. The wrap **250** includes an inner surface **276**, an outer surface **274**, a perimeter surface **278**, and a connecting surface **286**. The wrap **250** includes a first region **282** and a second region **284**. The transition between the first region **282** and the second region **284** is identified by a phantom line **285**.

[0088] The wrap **250** is similar to the wrap **150** (FIG. **3**) in that the wrap includes a gap (G) formed between circumferentially opposing portions of the perimeter surface **278**. The wrap **250**, however, includes a plurality of bodies. As a non-limiting example, the wrap **250** includes a first body **290** and a second body **292** circumferentially spaced from the first body **290**. As such, two gaps (G) are provided. While two bodies are illustrated, it will be appreciated that the wrap **250** includes any number of two or more bodies circumferentially spaced about the spar centerline axis **264**. While described as two completely separate bodies, it will be appreciated that the first body **290** is coupled to the second body **292**. As a non-limiting example, the first body **290** and the second body **292** can extend from a common body (not illustrated) such that the wrap **250** that extends about an entirety of or at least a portion of the spar centerline axis **264**. The wrap **250** is symmetric or asymmetrical about the spar centerline axis **264**.

[0089] The wrap **250** illustrated in FIG. **7** decreases the burden of coupling the wrap **250** to the spar **236**. As the wrap **250** includes at least two bodies, the total distance that each body of the wrap **250** has to be bent around the spar **236** is reduced in comparison with the wrap **150**, which can include a singular body.

[0090] FIG. **8** is a top-down cross-sectional view of an exemplary airfoil assembly **330** suitable for use as the composite airfoil assembly **130** of FIG. **2**. The composite airfoil assembly **330** is similar to the composite airfoil assembly **130**, **230**; therefore, like parts will be identified with like numerals increased to the **330** series with it being understood that the description of the composite airfoil assembly **130**, **230** applies to the composite airfoil assembly **330** unless indicated otherwise.

[0091] The composite airfoil assembly **330** includes a spar **336**. The spar **336** has a spar centerline axis **364**. The composite airfoil assembly **330** incudes a wrap **350**. The wrap **350** includes an inner surface **376** and an outer surface **374**.

[0092] The wrap **350** is similar to the wrap **150** (FIG. **3**), **250** (FIG. **7**) in that the wrap **350** at least partially encircles the spar centerline axis **364**. The wrap **350**, however, is formed as a continuous body that extends circumferentially continuously about an entirety of the spar centerline axis **364**.

[0093] The wrap **350** can include a composite material. The wrap **350** can be co-cured with or otherwise bonded to at least the spar **336**. As such, the wrap **350** and the spar **336** can form a unitary body.

[0094] The wrap **350**, when formed with a composite material, can further allow for additional tailoring of material properties of the wrap **350** when compared to a wrap formed with a metallic material. Composite materials can include a set of composite plies. Each composite ply can include at least one tow of fibers. As used herein, a tow refers to a bundle of continuous filaments or fibers, with each fiber in the tow having and extending along a respective centerline axis. When a composite ply includes more than one tow of fibers, the tow of fibers of the composite ply can be interwoven (e.g., braided or woven) together and subsequently bonded together to form a composite ply with at least a bidirectional fiber orientation. A composite ply with a single tow of fibers has a unidirectional fiber orientation. The variation of the number of tows, and thus the fiber orientation, is used to tailor the material properties of the composite ply. As a non-limiting example, a composite ply with a bidirectional fiber orientation can have a larger resilience to a shear stresses than a composite ply with a unidirectional fiber orientation.

[0095] The wrap **350** can be formed with any suitable number of composite plies having any suitable fiber orientation. The number of composite plies or the fiber orientation of the composite plies of the wrap **350** can be selected based on the anticipated forces that will be experienced along the composite airfoil assembly **330** where the wrap **350** is provided. In other words, the wrap **350** can be constructed to be best fit to withstand the anticipated forces that the wrap **350** will experience.

[0096] FIG. **9** is a schematic cross-sectional view of an exemplary airfoil assembly **430** suitable for use as the composite airfoil assembly **130** of FIG. **2**. The composite airfoil assembly **430** is similar to the composite airfoil assembly **130**, **230**, **330**; therefore, like parts will be identified with like numerals increased to the **430** series with it being understood that the description of the composite airfoil assembly **130**, **230**, **330** applies to the composite airfoil assembly **430** unless indicated otherwise.

[0097] The composite airfoil assembly **430** includes a spar **436**, a trunnion **434**, and a composite airfoil **432**. The composite airfoil **432** includes a composite skin **452**. The composite airfoil **432** includes a suction side **454** and a pressure side **456**. The spar **436** includes a stem **458** extending into a respective portion of the composite airfoil **432** and includes a base **460**. The base **460** and the stem **458** are interconnected by a transition **462**. The spar **436** has a spar centerline axis **464**. The trunnion **434** includes an upper edge **470** with an open top **472**, and an inner surface **466** defining a socket **468**. The socket **468** opens up to the open top **472**. The composite airfoil assembly **430** incudes a wrap **450**. The wrap **450** is formed as any suitable wrap **150** (FIG. **3**), **250** (FIG. **7**), **350** (FIG. **8**) described herein.

[0098] The composite airfoil assembly **430** is similar to the composite airfoil assembly **130** (FIG. **2**), **230** (FIG. **7**), **330** (FIG. **8**) in that the wrap **450** encircles at least the transition **462**. The composite airfoil assembly **430**, however, includes the composite skin **452** extends along the transition **462**. The composite skin **452** can terminate along the transition **462** or extend axially beyond the transition **462** and over a respective portion of the base **460**. At least a portion of the wrap **450** is provided radially over a respective portion of the composite skin **452** such that at least a portion of the composite skin **452** is radially sandwiched between the spar **436** and the wrap **450**. As a non-limiting example, the wrap **450** can extend over an entirety of the composite skin **452** that extends past the transition and towards the trunnion **434**. The wrap **450** can extend axially past where the composite skin **452** terminates and axially towards the trunnion **434** such that a first portion of the wrap **450** directly contacts and overlays the composite skin **452**, and a second portion of the wrap **450** directly contacts and overlays the spar **436**. Alternatively, the wrap **450** can axially terminate where the composite skin **452** axially terminates.

[0099] Providing the wrap **450** over at least a portion of the composite skin **452** allows for a stronger bond between the composite airfoil **432** and the spar **436**. The wrap **450** can be wrapped around a portion of the composite skin **452**, the spar **436**, or a combination thereof and subsequently coupled to the composite skin **452**, the spar **436** or a combination thereof. As a non-limiting example, the wrap **450** can be bonded to or co-cured with both the composite skin **452** and the spar **436** such that the wrap **450**, the composite skin **452** and the spar **436** form a unitary body. As a non-limiting example, the wrap **450** can be wrapped around the composite skin **452**, the spar

436, or a combination thereof such that the composite skin **452** is held in frictional contact with the spar **436** due to a compression of the wrap **450** around the composite skin **452**.
[0100] FIG. **10** is a schematic cross-sectional view of an exemplary airfoil assembly **530** suitable for use as the composite airfoil assembly **130** of FIG. **2**. The composite airfoil assembly **530** is similar to the composite airfoil assembly **130**, **230**, **330**, **430**; therefore, like parts will be identified with like numerals increased to the **530** series with it being understood that the description of the composite airfoil assembly **130**, **230**, **330**, **430** applies to the composite airfoil assembly **530** unless indicated otherwise.
[0101] The composite airfoil assembly **530** includes a spar **536**, a trunnion **534**, and a composite airfoil **532**. The composite airfoil **532** includes a composite skin **552**. The composite airfoil **532** includes a suction side **554** and a pressure side **556**. The spar **536** includes a stem **558** extending into a respective portion of the composite airfoil **532** and includes a base **560**. The base **560** and the stem **558** interconnected by a transition **562**. The spar **536** has a spar centerline axis **564**. The trunnion **534** includes an upper edge **570** with an open top **572**, and an inner surface **566** defining a socket **568**. The socket **568** opens up to the open top **572**. The composite airfoil assembly **530** incudes a wrap **550**. The wrap **550** is formed as any suitable wrap **150** (FIG. **3**), **250** (FIG. **7**), **350** (FIG. **8**), **450** (FIG. **9**) described herein.
[0102] The composite airfoil assembly **530** is similar to the composite airfoil assembly **130** (FIG. **2**), **230** (FIG. **7**), **330** (FIG. **8**), **430** (FIG. **9**) in that the wrap **550** encircles at least the transition **562**. At least a portion of the wrap **550**, like the wrap **450** (FIG. **9**), extends over the composite skin **552** such that at least a portion of the composite skin **552** is provided radially between a respective portion of the wrap **550** and the spar **536**. The wrap **550**, however, extends axially beyond the transition **562** an over a respective portion of the stem **558**.
[0103] The composite airfoil assembly **530** further includes a second wrap **592**. The second wrap **592** can be provided radially over at least a portion of the wrap **550**. The second wrap **592** can extend axially beyond the transition **562** and axially beyond a termination of the wrap **550**. Alternatively, the second wrap **592** can terminate axially along the transition **562**, terminate axially at a termination of the wrap **550** or a combination thereof.
[0104] The wrap **550** and the second wrap **592** can include the same or differing material or construction. As a non-limiting example, the wrap **550**, like the wrap **150** (FIG. **2**), can include a gap (not illustrated) formed between the circumferentially adjacent portions of the wrap **550**. As a non-limiting example, the wrap **550** can be formed like the wrap **150** (FIG. **2**), and the second wrap **592** can be formed like the wrap **350** (FIG. **8**). As such, the wrap **550** can include the gap, and the second wrap **592** can extend continuously about the spar centerline axis **564** including circumferentially over the gap. As such, at least a portion of the second wrap **592** can contact or otherwise directly overlay a respective portion of the spar **536** (e.g., through the gap). As a non-limiting example, the wrap **550** or the second wrap **592** can include a metallic material while the other of the wrap **550** or the second wrap **592** can include a composite material. As a non-limiting example, the wrap **550** can extend circumferentially about less than an entirety of the spar centerline axis **564**, while the second wrap **592** can extend circumferentially about greater than or equal to the entirety of the spar centerline axis **564**.
[0105] Benefits associated with the present disclosure include a variable pitch airfoil assembly with a greater resilience to the operational forces when compared to a conventional variable pitch airfoil assembly. For example, the conventional variable pitch airfoil assembly can include a spar extending from a composite airfoil and into a trunnion. The spar, however, will experience a relatively large force at the location where the spar transitions from the stem to the base or otherwise where the spar exits the composite airfoil. This relatively large force can cause damage to the spar itself. The variable pitch airfoil assembly as described herein, however, includes at least one of the wrap or the second wrap, which are used to strengthen the region of the spar that will experience these relatively large forces. This, in turn, limits or otherwise minimizes the damage

associated with the operational forces experienced along the variable pitch airfoil assembly when compared to the conventional variable pitch airfoil assembly.

[0106] To the extent not already described, the different features and structures of the various embodiments can be used in combination, or in substitution with each other as desired. That one feature is not illustrated in all of the embodiments is not meant to be construed that it cannot be so illustrated, but is done for brevity of description. Thus, the various features of the different embodiments can be mixed and matched as desired to form new embodiments, whether or not the new embodiments are expressly described. All combinations or permutations of features described herein are covered by this disclosure.

[0107] This written description uses examples to describe aspects of the disclosure described herein, including the best mode, and also to enable any person skilled in the art to practice aspects of the disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of aspects of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

[0108] Further aspects are provided by the subject matter of the following clauses:

[0109] A composite airfoil assembly comprising a composite airfoil having an outer wall extending between a root and a tip, and defining an interior, the composite airfoil having a composite skin forming at least a portion of the outer wall, a spar having a spar centerline axis, a stem extending into at least a portion of the interior, a base located exterior the root of the composite airfoil, and a transition interconnecting the stem and the base, and a wrap at least partially encircling the transition.

[0110] The composite airfoil assembly of any preceding clause, wherein the wrap comprises a metallic material.

[0111] The composite airfoil assembly of any preceding clause, wherein the wrap fully circumferentially encircles the transition.

[0112] The composite airfoil assembly of any preceding clause, wherein the wrap comprises a composite material.

[0113] The composite airfoil assembly of any preceding clause, wherein the composite skin extends axially over the transition with respect to the spar centerline axis.

[0114] The composite airfoil assembly of any preceding clause, wherein the composite skin extends radially between the wrap and the transition.

[0115] The composite airfoil assembly of any preceding clause, wherein the wrap extends axially beyond the transition and over at least a portion of the composite skin.

[0116] The composite airfoil assembly of any preceding clause, wherein the wrap is a first wrap, the composite airfoil assembly further comprising a second wrap at least partially encircling the first wrap.

[0117] The composite airfoil assembly of any preceding clause, wherein the first wrap includes a metallic material and the second wrap includes a composite material.

[0118] The composite airfoil assembly of any preceding clause, wherein the first wrap extends circumferentially about less than an entirety of the spar centerline axis and the second wrap extends circumferentially greater than or equal to the entirety of the spar centerline axis.

[0119] The composite airfoil assembly of any preceding clause, wherein the wrap includes at least two bodies circumferentially spaced from one another.

[0120] The composite airfoil assembly of any preceding clause, wherein the wrap includes circumferentially distal ends with a gap formed therebetween.

[0121] The composite airfoil assembly of any preceding clause, wherein the gap is larger than zero.

[0122] The composite airfoil assembly of any preceding clause, wherein the wrap includes a cross-sectional area when viewed along a horizontal plane perpendicular to the spar centerline axis, the cross-sectional area including a first region with a first thickness and a second region with a second thickness that is less than the first thickness.

[0123] The composite airfoil assembly of any preceding clause, wherein the second thickness linearly or non-linearly decreases in size from the first region and to a thickness of the wrap.

[0124] The composite airfoil assembly of any preceding clause, wherein the first thickness is constant.

[0125] A turbine engine including the composite airfoil assembly of any preceding clause, the turbine engine further comprising a fan section, a compressor section, a combustion section, and a turbine section in serial flow arrangement and defining a stator portion and a rotor portion, which rotates about an engine centerline, the composite airfoil being provided within the rotor portion.

[0126] A turbine engine including the composite airfoil assembly of any preceding clause, the turbine engine being an unducted turbine engine and the composite airfoil is an external fan blade.

[0127] The turbine engine of any preceding clause, wherein the wrap comprises a metallic material.

[0128] The turbine engine of any preceding clause, wherein the wrap fully circumferentially encircles the transition.

[0129] The turbine engine of any preceding clause, wherein the wrap comprises a composite material.

[0130] The turbine engine of any preceding clause, wherein the composite skin extends axially over the transition with respect to the spar centerline axis.

[0131] The turbine engine of any preceding clause, wherein the composite skin extends radially between the wrap and the transition.

[0132] The turbine engine of any preceding clause, wherein the wrap extends axially beyond the transition and over at least a portion of the composite skin.

[0133] The turbine engine of any preceding clause, wherein the wrap is a first wrap, the composite airfoil assembly further comprising a second wrap at least partially encircling the first wrap.

[0134] The turbine engine of any preceding clause, wherein the first wrap includes a metallic material and the second wrap includes a composite material.

[0135] The turbine engine of any preceding clause, wherein the first wrap extends circumferentially about less than an entirety of the spar centerline axis and the second wrap extends circumferentially greater than or equal to the entirety of the spar centerline axis.

[0136] extends circumferentially greater than or equal to the entirety of the spar centerline axis.

[0137] The turbine engine of any preceding clause, wherein the wrap includes at least two bodies circumferentially spaced from one another.

[0138] The turbine engine of any preceding clause, wherein the wrap includes circumferentially distal ends with a gap formed therebetween.

[0139] The turbine engine of any preceding clause, wherein the gap is larger than zero.

[0140] The turbine engine of any preceding clause, wherein the wrap includes a cross-sectional area when viewed along a horizontal plane perpendicular to the spar centerline axis, the cross-sectional area including a first region with a first thickness and a second region with a second thickness that is less than the first thickness.

[0141] The turbine engine of any preceding clause, wherein the second thickness linearly or non-linearly decreases in size from the first region and to a thickness of the wrap.

[0142] The turbine engine of any preceding clause, wherein the first thickness is constant.

[0143] A composite variable pitch airfoil assembly comprising a composite airfoil having an outer wall extending between a root and a tip, and defining an interior, the composite airfoil having a composite skin forming at least a portion of the outer wall, a spar having a spar centerline axis, a stem extending into at least a portion of the interior, a base located exterior the root of the composite airfoil, and a transition interconnecting the stem and the base, and a trunnion having an upper edge with an open top, and a wall having a set of interior surfaces defining a socket

extending from the open top, with at least a portion of the base extending through the open top and into the socket, and a wrap at least partially encircling the transition.
[0144] The composite variable pitch airfoil assembly of any preceding clause, wherein the wrap terminates axially prior to the trunnion, with respect to the spar centerline axis.
[0145] The composite variable pitch airfoil assembly of any preceding clause, wherein the wrap comprises a metallic material.
[0146] The composite variable pitch airfoil assembly of any preceding clause, wherein the wrap fully circumferentially encircles the transition.
[0147] The composite variable pitch airfoil assembly of any preceding clause, wherein the wrap comprises a composite material.
[0148] The composite variable pitch airfoil assembly of any preceding clause, wherein the composite skin extends axially over the transition with respect to the spar centerline axis.
[0149] The composite variable pitch airfoil assembly of any preceding clause, wherein the composite skin extends radially between the wrap and the transition.
[0150] The composite variable pitch airfoil assembly of any preceding clause, wherein the wrap extends axially beyond the transition and over at least a portion of the composite skin.
[0151] The composite variable pitch airfoil assembly of any preceding clause, wherein the wrap is a first wrap, the composite airfoil assembly further comprising a second wrap at least partially encircling the first wrap.
[0152] The composite variable pitch airfoil assembly of any preceding clause, wherein the first wrap includes a metallic material and the second wrap includes a composite material.
[0153] The composite variable pitch airfoil assembly of any preceding clause, wherein the first wrap extends circumferentially about less than an entirety of the spar centerline axis and the second wrap extends circumferentially greater than or equal to the entirety of the spar centerline axis.
[0154] The composite variable pitch airfoil assembly of any preceding clause, wherein the wrap includes at least two bodies circumferentially spaced from one another.
[0155] The composite variable pitch airfoil assembly of any preceding clause, wherein the wrap includes circumferentially distal ends with a gap formed therebetween.
[0156] The composite variable pitch airfoil assembly of any preceding clause, wherein the gap is larger than zero.
[0157] The composite variable pitch airfoil assembly of any preceding clause, wherein the wrap includes a cross-sectional area when viewed along a horizontal plane perpendicular to the spar centerline axis, the cross-sectional area including a first region with a first thickness and a second region with a second thickness that is less than the first thickness.
[0158] The composite variable pitch airfoil assembly of any preceding clause, wherein the second thickness linearly or non-linearly decreases in size from the first region and to a thickness of the wrap.
[0159] The composite variable pitch airfoil assembly of any preceding clause, wherein the first thickness is constant.

Claims

1. (canceled)
2. The composite airfoil assembly of claim **22**, wherein the wrap comprises a metallic material.
3. The composite airfoil assembly of claim **22**, wherein the wrap fully circumferentially encircles the transition.
4. The composite airfoil assembly of claim **22**, wherein the wrap comprises a composite material.
5. The composite airfoil assembly of claim **22**, wherein the composite skin extends axially over the transition with respect to the spar centerline axis.
6. A composite airfoil assembly comprising: a composite airfoil having an outer wall extending

between a root and a tip, and defining an interior, the composite airfoil having a composite skin forming at least a portion of the outer wall; a spar having a spar centerline axis, a stem extending into at least a portion of the interior, a base located exterior the root of the composite airfoil, and a transition interconnecting the stem and the base; and a wrap at least partially encircling the transition; wherein the composite skin extends axially over the transition with respect to the spar centerline, and the composite skin is located radially between the wrap and the transition with respect to the spar centerline.

7. A composite airfoil assembly comprising: a composite airfoil having an outer wall extending between a root and a tip, and defining an interior, the composite airfoil having a composite skin forming at least a portion of the outer wall; a spar having a spar centerline axis, a stem extending into at least a portion of the interior, a base located exterior the root of the composite airfoil, and a transition interconnecting the stem and the base; and a wrap at least partially encircling the transition; wherein the wrap extends axially beyond the transition and over at least a portion of the composite skin.

8. The composite airfoil assembly of claim **22**, wherein the wrap is a first wrap, the composite airfoil assembly further comprising a second wrap at least partially encircling the first wrap.

9. A composite airfoil assembly comprising: a composite airfoil having an outer wall extending between a root and a tip, and defining an interior, the composite airfoil having a composite skin forming at least a portion of the outer wall; a spar having a spar centerline axis, a stem extending into at least a portion of the interior, a base located exterior the root of the composite airfoil, and a transition interconnecting the stem and the base; a first wrap at least partially encircling the transition including a metallic material; and a second wrap at least partially encircling the first wrap, the second wrap including a composite material.

10. The composite airfoil assembly of claim 8, wherein the first wrap extends circumferentially about less than an entirety of the spar centerline axis and the second wrap extends circumferentially greater than or equal to the entirety of the spar centerline axis.

11. (canceled)

12. A composite airfoil assembly comprising: a composite airfoil having an outer wall extending between a root and a tip, and defining an interior, the composite airfoil having a composite skin forming at least a portion of the outer wall; a spar having a spar centerline axis, a stem extending into at least a portion of the interior, a base located exterior the root of the composite airfoil, and a transition interconnecting the stem and the base; and a wrap at least partially encircling the transition; wherein the wrap includes circumferentially distal ends with a gap formed therebetween.

13. The composite airfoil assembly of claim 12, wherein the gap is larger than zero.

14. The composite airfoil assembly of claim **22**, wherein the wrap includes a cross-sectional area when viewed along a horizontal plane perpendicular to the spar centerline axis, the cross-sectional area including a first region with a first thickness and a second region with a second thickness that is less than the first thickness.

15. The composite airfoil assembly of claim 14, wherein the second thickness linearly or non-linearly decreases in size from the first region and to a minimum thickness of the wrap.

16. The composite airfoil assembly of claim 14, wherein the first thickness is constant.

17. A turbine engine including the composite airfoil assembly of claim **22**, the turbine engine further comprising a fan section, a compressor section, a combustion section, and a turbine section in serial flow arrangement and defining a stator portion and a rotor portion, which rotates about an engine centerline, the composite airfoil being provided within the rotor portion.

18. A turbine engine including the composite airfoil assembly of claim **22**, the turbine engine being an unducted turbine engine and the composite airfoil is an external fan blade.

19. The composite airfoil assembly of claim **22**, wherein the composite airfoil assembly is a composite variable pitch airfoil assembly.

20. (canceled)

21. The composite airfoil assembly of claim 19, wherein the composite airfoil assembly is located within a turbine engine having a fan section having a plurality of fan blades, with the composite airfoil assembly being provided within the plurality of fan blades.

22. A composite airfoil assembly comprising: a composite airfoil having an outer wall extending between a root and a tip, and defining an interior, the composite airfoil having a composite skin forming at least a portion of the outer wall; a spar having a spar centerline axis, a stem extending into at least a portion of the interior, a base located exterior the root of the composite airfoil, and a transition interconnecting the stem and the base; and a wrap at least partially encircling the transition, the wrap contacting a respective portion of the spar and the composite airfoil.

23. The composite airfoil assembly of claim 22, wherein the wrap includes a first region and a second region extending from the first region and to a perimeter surface of the wrap, the second region being defined by a portion of the wrap that decreases in thickness between the first region and the perimeter surface.