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TURBOFAN ENGINE HAVING ANGLED INLET PRE-SWIRL VANES

Abstract

A turbofan engine is provided. The turbofan engine includes a fan having a plurality of fan blades; a turbomachine operably coupled to the fan for driving the fan, the turbomachine having a compressor section, a combustion section, and a turbine section in serial flow order and together defining a core air flowpath; a nacelle surrounding and at least partially enclosing the fan, the nacelle defining a radius and a longitudinal axis; and an inlet pre-swirl vane located upstream of the plurality of fan blades and defining a chord, the inlet pre-swirl vane coupled to the nacelle, wherein the inlet pre-swirl vane is angled at a first angle with respect to the radius of the nacelle, and wherein the chord of the inlet pre-swirl vane is angled at a second angle with respect to the longitudinal axis of the nacelle.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a Divisional application of U.S. application Ser. No. 18/755,054 filed Jun. 26, 2024, which is a Divisional application of U.S. application Ser. No. 17/676,454 filed Feb. 21, 2022, each of which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present subject matter relates generally to a gas turbine engine, or more particularly to a gas turbine engine configured to guide an airflow at an inlet of a nacelle and to direct incoming objects towards an outer portion of the engine and away from a core of the engine.

BACKGROUND

[0003] A turbofan engine generally includes a fan having a plurality of fan blades and a turbomachine arranged in flow communication with one another. Additionally, the turbomachine of the turbofan engine generally includes, in serial flow order, a compressor section, a combustion section, a turbine section, and an exhaust section. In operation, air is provided from the fan to an inlet of the compressor section where one or more axial compressors progressively compress the air until it reaches the combustion section. Fuel is mixed with the compressed air and burned within the combustion section to provide combustion gases. The combustion gases are routed from the combustion section to the turbine section. The flow of combustion gasses through the turbine section drives the turbine section and is then routed through the exhaust section, e.g., to atmosphere.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] 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:

[0005] FIG. 1 is a schematic cross-sectional view of an exemplary gas turbine engine according to an exemplary embodiment of the present subject matter.

[0006] FIG. 2 is a close-up, schematic, cross-sectional view of a forward end of the exemplary gas turbine engine of FIG. 1 according to an exemplary embodiment of the present subject matter.

[0007] FIG. 3 is a schematic view of an inlet to the exemplary gas turbine engine of FIG. 1, along an axial direction of the gas turbine engine of FIG. 1 according to an exemplary embodiment of the present subject matter.

[0008] FIG. 4 it is a schematic view of an inlet to a gas turbine engine in accordance with another exemplary embodiment of the present disclosure.

[0009] FIG. 5 is a schematic view of an inlet to the exemplary gas turbine engine of FIG. 1, along an axial direction of the gas turbine engine of FIG. 1 according to another exemplary embodiment of the present subject matter.

[0010] FIG. 6 is a cross-sectional view of a part span inlet guide vane of the exemplary gas turbine

engine of FIG. 1 at a first location along a span of the part span inlet guide vane.

[0011] FIG. 7 is a cross-sectional view of the part span inlet guide vane of the exemplary gas turbine engine of FIG. 1 at a second location along the span of the part span inlet guide vane.

[0012] FIG. 8 is a schematic view of an inlet to the exemplary gas turbine engine of FIG. 1, along an axial direction of the gas turbine engine of FIG. 1 according to another exemplary embodiment of the present subject matter.

[0013] FIG. 9 is a schematic view of an inlet to the exemplary gas turbine engine of FIG. 1, along an axial direction of the gas turbine engine of FIG. 1 according to another exemplary embodiment of the present subject matter.

[0014] FIG. 10 is a schematic view of an inlet to the exemplary gas turbine engine of FIG. 1, along an axial direction of the gas turbine engine of FIG. 1 according to another exemplary embodiment of the present subject matter.

[0015] FIG. 11 is a schematic view of an inlet to the exemplary gas turbine engine of FIG. 1, along an axial direction of the gas turbine engine of FIG. 1 according to another exemplary embodiment of the present subject matter.

[0016] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate exemplary embodiments of the disclosure, and such exemplifications are not to be construed as limiting the scope of the disclosure in any manner.

DETAILED DESCRIPTION

[0017] Reference will now be made in detail to present embodiments of the disclosure, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the disclosure.

[0018] The following description is provided to enable those skilled in the art to make and use the described embodiments contemplated for carrying out the disclosure. Various modifications, equivalents, variations, and alternatives, however, will remain readily apparent to those skilled in the art. Any and all such modifications, variations, equivalents, and alternatives are intended to fall within the scope of the present disclosure.

[0019] The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any implementation described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other implementations. Additionally, unless specifically identified otherwise, all embodiments described herein should be considered exemplary.

[0020] For purposes of the description hereinafter, the terms “upper”, “lower”, “right”, “left”, “vertical”, “horizontal”, “top”, “bottom”, “lateral”, “longitudinal”, and derivatives thereof shall relate to the disclosure as it is oriented in the drawing figures. However, it is to be understood that the disclosure may assume various alternative variations, except where expressly specified to the contrary. It is also to be understood that the specific devices illustrated in the attached drawings, and described in the following specification, are simply exemplary embodiments of the disclosure. Hence, specific dimensions and other physical characteristics related to the embodiments disclosed herein are not to be considered as limiting.

[0021] As used herein, the terms “first”, “second”, and “third” may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components.

[0022] The terms “forward” and “aft” refer to relative positions within a gas turbine engine, with forward referring to a position closer to an engine inlet and aft referring to a position closer to an engine nozzle or exhaust.

[0023] The terms “upstream” and “downstream” refer to the relative direction with respect to fluid flow in a fluid pathway. For example, “upstream” refers to the direction from which the fluid flows, and “downstream” refers to the direction to which the fluid flows.

[0024] The singular forms “a”, “an”, and “the” include plural references unless the context clearly dictates otherwise.

[0025] Additionally, the terms “low,” “high,” or their respective comparative degrees (e.g., lower, higher, where applicable) each refer to relative speeds or pressures within an engine, unless otherwise specified. For example, a “low-pressure turbine” operates at a pressure generally lower than a “high-pressure turbine.” Alternatively, unless otherwise specified, the aforementioned terms may be understood in their superlative degree. For example, a “low-pressure turbine” may refer to the lowest maximum pressure turbine within a turbine section, and a “high-pressure turbine” may refer to the highest maximum pressure turbine within the turbine section. An engine of the present disclosure may also include an intermediate pressure turbine, e.g., an engine having three spools.

[0026] Approximating language, as used herein throughout the specification and claims, is applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as “about”, “approximately”, and “substantially”, are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value, or the precision of the methods or machines for constructing or manufacturing the components and/or systems. For example, the approximating language may refer to being within a 1, 2, 4, 10, 15, or 20 percent margin. These approximating margins may apply to a single value, either or both endpoints defining numerical ranges, and/or the margin for ranges between endpoints.

[0027] Here and throughout the specification and claims, range limitations are combined and interchanged, such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. For example, all ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other.

[0028] As used herein, the term “fan pressure ratio” refers to a ratio of an air pressure immediately downstream of the fan blades of the fan during operation of the fan to an air pressure immediately upstream of the fan blades of the fan during operation of the fan.

[0029] As used herein, the term “rated speed” with reference to a turbofan engine refers to a maximum rotational speed that the turbofan engine may achieve while operating properly. For example, the turbofan engine may be operating at the rated speed during maximum load operations, such as during takeoff operations.

[0030] Also as used herein, the term “fan tip speed” as defined by the plurality of fan blades of the fan refers to a linear speed of an outer tip of a fan blade along a radial direction during operation of the fan.

[0031] The present disclosure is generally related to an inlet pre-swirl vane configured as a plurality of part span inlet guide vanes for a turbofan engine. In the present disclosure, the plurality of part span inlet guide vanes are angled at a first angle with respect to a radius of an outer nacelle of the turbofan engine. Furthermore, the plurality of part span inlet guide vanes define a chord and the chord of the part span inlet guide vane is angled at a second angle with respect to the longitudinal axis of the outer nacelle.

[0032] In this manner, the plurality of part span inlet guide vanes are configured to direct incoming objects towards an outer portion of the turbofan engine. The plurality of part span inlet guide vanes are configured to direct incoming objects away from a core air flowpath of the turbofan engine and towards a bypass airflow passage. This provides a deflection mechanism that facilitates ingestion of an object into an outer portion of the turbofan engine by minimizing the chance that the object travels to the core of the turbofan engine. Such objects may include bird strikes, hail, ice, sandstorms, debris, and other foreign objects.

[0033] Furthermore, in this manner, the plurality of part span inlet guide vanes are also configured to pre-swirl an airflow provided through an inlet of the outer nacelle, upstream of the plurality of fan blades of a fan. As discussed herein, pre-swirling the airflow provided through the inlet of the

outer nacelle prior to such airflow reaching the plurality of fan blades of the fan may reduce separation losses and/or shock losses, allowing the fan to operate with relatively high fan tip speeds with less losses in efficiency. Furthermore, in this manner, the plurality of part span inlet guide vanes are also configured to minimize flutter and maintain laminar air flow over the part span inlet guide vanes and minimize turbulence in the inlet.

[0034] Referring now to the drawings, wherein identical numerals indicate the same elements throughout the figures, FIG. 1 is a schematic cross-sectional view of a gas turbine engine in accordance with an exemplary embodiment of the present disclosure. More particularly, for the embodiment of FIG. 1, the gas turbine engine is an aeronautical, turbofan jet engine **10**, referred to herein as “turbofan engine **10**”, configured to be mounted to an aircraft, such as in an under-wing configuration or tail-mounted configuration. As shown in FIG. 1, the turbofan engine **10** defines an axial direction A (extending parallel to a longitudinal centerline **12** provided for reference), a radial direction R, and a circumferential direction (i.e., a direction extending about the axial direction A; not depicted). In general, the turbofan engine **10** includes a fan section **14** and a turbomachine **16** disposed downstream from the fan section **14** (the turbomachine **16** sometimes also, or alternatively, referred to as a “core turbine engine”).

[0035] The exemplary turbomachine **16** depicted generally includes a substantially tubular outer casing **18** that defines an annular inlet **20**. The outer casing **18** encases, in serial flow relationship, a compressor section including a first, booster or low pressure (LP) compressor **22** and a second, high pressure (HP) compressor **24**; a combustion section **26**; a turbine section including a first, high pressure (HP) turbine **28** and a second, low pressure (LP) turbine **30**; and a jet exhaust nozzle section **32**. A high pressure (HP) shaft **34** drivingly connects the HP turbine **28** to the HP compressor **24**. A low pressure (LP) shaft **36** drivingly connects the LP turbine **30** to the LP compressor **22**. The compressor section, combustion section **26**, turbine section, and jet exhaust nozzle section **32** are arranged in serial flow order and together define a core air flowpath **37** through the turbomachine **16**. It is also contemplated that the present disclosure is compatible with an engine having an intermediate pressure turbine, e.g., an engine having three spools.

[0036] Referring still to the embodiment of FIG. 1, the fan section **14** includes a variable pitch, single stage fan **38**, the turbomachine **16** operably coupled to the fan **38** for driving the fan **38**. The fan **38** includes a plurality of rotatable fan blades **40** coupled to a disk **42** in a spaced apart manner. As depicted, the fan blades **40** extend outwardly from disk **42** generally along the radial direction R. Each fan blade **40** is rotatable relative to the disk **42** about a pitch axis P by virtue of the fan blades **40** being operatively coupled to a suitable actuation member **44** configured to collectively vary the pitch of the fan blades **40**, e.g., in unison. The fan blades **40**, disk **42**, and actuation member **44** are together rotatable about the longitudinal centerline **12** by LP shaft **36** across a power gear box **46**. The power gear box **46** includes a plurality of gears for stepping down the rotational speed of the LP shaft **36** to a more efficient rotational fan speed. Accordingly, for the embodiment depicted, the turbomachine **16** is operably coupled to the fan **38** through the power gear box **46**.

[0037] In exemplary embodiments, the fan section **14** includes twenty-two (22) or fewer fan blades **40**. In certain exemplary embodiments, the fan section **14** includes twenty (20) or fewer fan blades **40**. In certain exemplary embodiments, the fan section **14** includes eighteen (18) or fewer fan blades **40**. In certain exemplary embodiments, the fan section **14** includes sixteen (16) or fewer fan blades **40**. In certain exemplary embodiments, it is contemplated that the fan section **14** includes other number of fan blades **40** for a particular application.

[0038] During operation of the turbofan engine **10**, the fan **38** defines a fan pressure ratio and the plurality of fan blades **40** each define a fan tip speed. The exemplary turbofan engine **10** depicted defines a relatively high fan tip speed and relatively low fan pressure ratio during operation of the turbofan engine at a rated speed. As used herein, the term “fan pressure ratio” refers to a ratio of an air pressure immediately downstream of the fan blades **40** during operation of the fan **38** to an air

pressure immediately upstream of the fan blades **40** during operation of the fan **38**. For the embodiment depicted in FIG. **1**, the fan **38** of the turbofan engine **10** defines a relatively low fan pressure ratio. For example, the turbofan engine **10** depicted defines a fan pressure ratio less than or equal to about 1.5. For example, in certain exemplary embodiments, the turbofan engine **10** may define a fan pressure ratio less than or equal to about 1.4. In certain exemplary embodiments, it is contemplated that the turbofan engine **10** may define other fan pressure ratios for a particular application. The fan pressure ratio may be the fan pressure ratio of the fan **38** during operation of the turbofan engine **10**, such as during operation of the turbofan engine **10** at a rated speed.

[0039] As used herein, the term “rated speed” with reference to the turbofan engine **10** refers to a maximum rotational speed that the turbofan engine **10** may achieve while operating properly. For example, the turbofan engine **10** may be operating at the rated speed during maximum load operations, such as during takeoff operations.

[0040] Also as used herein, the term “fan tip speed” defined by the plurality of fan blades **40** refers to a linear speed of an outer tip of a fan blade **40** along the circumferential direction during operation of the fan **38**. In exemplary embodiments, the turbofan engine **10** of the present disclosure causes the fan blades **40** of the fan **38** to rotate at a relatively high rotational speed. For example, during operation of the turbofan engine **10** at the rated speed, the fan tip speed of each of the plurality of fan blades **40** is greater than or equal to 1,000 feet per second and less than or equal to 2,250 feet per second. In certain exemplary embodiments, during operation of the turbofan engine **10** at the rated speed, the fan tip speed of each of the fan blades **40** may be greater than or equal to 1,250 feet per second and less than or equal to 2,250 feet per second. In certain exemplary embodiments, during operation of the turbofan engine **10** at the rated speed, the fan tip speed of each of the fan blades **40** may be greater than or equal to about 1,350 feet per second, such as greater than about 1,450 feet per second, such as greater than about 1,550 feet per second, and less than or equal to 2,250 feet per second. In certain exemplary embodiments, it is contemplated that during operation of the turbofan engine **10** at the rated speed, the fan tip speed of each of the fan blades **40** may define other ranges for a particular application.

[0041] Referring still to the exemplary embodiment of FIG. **1**, the disk **42** is covered by rotatable front nacelle or hub **48** aerodynamically contoured to promote an airflow through the plurality of fan blades **40**. Additionally, the exemplary fan section **14** includes an annular fan casing or outer nacelle **50** that at least partially, and for the embodiment depicted, circumferentially, surrounds the fan **38** and at least a portion of the turbomachine **16**.

[0042] More specifically, the outer nacelle **50** includes an inner wall **52** and a downstream section **54** of the inner wall **52** of the outer nacelle **50** extends over an outer portion of the turbomachine **16** so as to define a bypass airflow passage **56** therebetween. Additionally, for the embodiment depicted, the outer nacelle **50** is supported relative to the turbomachine **16** by a plurality of circumferentially spaced outlet guide vanes **55**. The outer nacelle **50** includes an inlet **60** at a leading edge **61** of the outer nacelle **50**.

[0043] During operation of the turbofan engine **10**, a volume of air **58** enters the turbofan engine **10** through the inlet **60** of the outer nacelle **50** and/or fan section **14**. As the volume of air **58** passes across the fan blades **40**, a first portion of the air **58** as indicated by arrows **62** is directed or routed into the bypass airflow passage **56** and a second portion of the air **58** as indicated by arrow **64** is directed or routed into the core air flowpath **37**. The ratio between an amount of airflow through the bypass airflow passage **56** (i.e., the first portion of air indicated by arrows **62**) to an amount of airflow through the core air flowpath **37** (i.e., the second portion of air indicated by arrows **64**) is known as a bypass ratio.

[0044] Referring still to FIG. **1**, the compressed second portion of air indicated by arrows **64** from the compressor section mixes with fuel and is burned within the combustion section to provide combustion gases **66**. The combustion gases **66** are routed from the combustion section **26**, through the HP turbine **28** where a portion of thermal and/or kinetic energy from the combustion gases **66** is

extracted via sequential stages of HP turbine stator vanes **68** that are coupled to the outer casing **18** and HP turbine rotor blades **70** that are coupled to the HP shaft **34**, thus causing the HP shaft **34** to rotate, thereby supporting operation of the HP compressor **24**. The combustion gases **66** are then routed through the LP turbine **30** where a second portion of thermal and kinetic energy is extracted from the combustion gases **66** via sequential stages of LP turbine stator vanes **72** that are coupled to the outer casing **18** and LP turbine rotor blades **74** that are coupled to the LP shaft **36**, thus causing the LP shaft **36** to rotate, thereby supporting operation of the LP compressor **22** and/or rotation of the fan **38**.

[0045] The combustion gases **66** are subsequently routed through the jet exhaust nozzle section **32** of the turbomachine **16** to provide propulsive thrust. Simultaneously, the pressure of the first portion of air indicated by arrows **62** is substantially increased as the first portion of air **62** is routed through the bypass airflow passage **56** before it is exhausted from a fan nozzle exhaust section **76** of the turbofan **10**, also providing propulsive thrust. The HP turbine **28**, the LP turbine **30**, and the jet exhaust nozzle section **32** at least partially define a hot gas path **78** for routing the combustion gases **66** through the turbomachine **16**.

[0046] Referring still to FIG. **1**, the turbofan engine **10** of the present disclosure also provides pre-swirling flow forward of a tip of the fan blade **40** as described herein. For example, the turbofan engine **10** additionally includes an inlet pre-swirl vane, e.g., configured as a plurality of part span inlet guide vanes **100**, as described in greater detail herein.

[0047] In some exemplary embodiments, it will be appreciated that the exemplary turbofan engine **10** of the present disclosure may be a relatively large power class turbofan engine **10**. Accordingly, when operated at the rated speed, the turbofan engine **10** may be configured to generate a relatively large amount of thrust. More specifically, when operated at the rated speed, the turbofan engine **10** may be configured to generate at least about 20,000 pounds of thrust, such as at least about 25,000 pounds of thrust, such as at least about 30,000 pounds of thrust, and up to, e.g., about 150,000 pounds of thrust. Accordingly, the turbofan engine **10** may be referred to as a relatively large power class gas turbine engine.

[0048] Moreover, it should be appreciated that the exemplary turbofan engine **10** depicted in FIG. **1** is by way of example only, and that in other exemplary embodiments, the turbofan engine **10** may have any other suitable configuration. For example, in certain exemplary embodiments, the fan may not be a variable pitch fan, the engine may not include a reduction gearbox (e.g., power gearbox **46**) driving the fan, may include any other suitable number or arrangement of shafts, spools, compressors, turbines, etc.

[0049] As discussed above, the turbofan engine **10** of the present disclosure also provides pre-swirling flow forward a tip of the fan blade **40**. Referring now also to FIG. **2**, a close-up, cross-sectional view of the fan section **14** and forward end of the turbomachine **16** of the exemplary turbofan engine **10** of FIG. **1** is provided. In exemplary embodiments, the turbofan engine **10** includes an inlet pre-swirl vane located upstream of the plurality of fan blades **40** of the fan **38** and coupled to the outer nacelle **50**. For example, the inlet pre-swirl vane can be directly attached to, indirectly attached to, or integrated into the outer nacelle **50**. More specifically, for the embodiment of FIGS. **1** and **2**, the inlet pre-swirl vane is configured as a plurality of part span inlet guide vanes **100**. The plurality of part span inlet guide vanes **100** are each cantilevered from the outer nacelle **50** (such as from the inner wall **52** of the outer nacelle **50**) at a location forward of the plurality of fan blades **40** of the fan **38** along the axial direction A and aft of the inlet **60** of the outer nacelle **50**. More specifically, each of the plurality of part span inlet guide vanes **100** define an outer end **102** along the radial direction R, and are coupled to the outer nacelle **50** at the radially outer end **102** through a suitable connection means (not shown). For example, each of the plurality of part span inlet guide vanes **100** may be bolted to the inner wall **52** of the outer nacelle **50** at the outer end **102**, welded to the inner wall **52** of the outer nacelle **50** at the outer end **102**, or coupled to the outer nacelle **50** in any other suitable manner at the outer end **102**.

[0050] Referring still to FIG. 2, in an exemplary embodiment, a nacelle assembly **80** of the present disclosure includes the outer nacelle **50** and the inlet pre-swirl vane, e.g., a plurality of part span inlet guide vanes **100**. Further, for the embodiment depicted, the plurality of part span inlet guide vanes **100** extend generally along the radial direction R from the outer end **102** to an inner end **104** (i.e., an inner end **104** along the radial direction R). Moreover, as will be appreciated, for the embodiment depicted, each of the plurality of part span inlet guide vanes **100** are unconnected with an adjacent part span inlet guide vane **100** at the respective inner ends **104** (i.e., adjacent part span inlet guide vanes **100** do not contact one another at the radially inner ends **104**, and do not include any intermediate connection members at the radially inner ends **104**, such as a connection ring, strut, etc.). More specifically, for the embodiment depicted, each part span inlet guide vane **100** is completely supported by a connection to the outer nacelle **50** at the respective outer end **102** (and not through any structure extending, e.g., between adjacent part span inlet guide vanes **100** at a location inward of the outer end **102** along the radial direction R). As will be discussed below, such may reduce an amount of turbulence generated by the part span inlet guide vanes **100**.

[0051] Moreover, as depicted, each of the plurality of part span inlet guide vanes **100** do not extend completely between the outer nacelle **50** and, e.g., the hub **48** of the turbofan engine **10**. More specifically, for the embodiment depicted, each of the plurality of inlet guide vanes define an inlet guide vane (“IGV”) span **106** along the radial direction R, which refers to a measure along the radial direction R between the outer end **102** and the inner end **104** of the part span inlet guide vane **100** at the leading edge **108** of the part span inlet guide vane **100**. Each of the plurality of part span inlet guide vanes **100** further define a leading edge **108** and a trailing edge **110**. Similarly, it will be appreciated, that the plurality of fan blades **40** of the fan **38** define a fan blade span **112** along the radial direction R, which refers to a measure along the radial direction R between a radially outer tip and a base of the fan blade **40** at the leading edge **114** of the respective fan blade **40**. Each of the plurality of fan blades **40** of the fan **38** also defines a leading edge **114** and a trailing edge **116**.

[0052] For the embodiment depicted, the IGV span **106** is at least about five percent of the fan blade span **112** and up to about fifty-five percent of the fan blade span **112**. For example, in certain exemplary embodiments, the IGV span **106** may be between about fifteen percent of the fan blade span **112** and about forty-five percent of the fan blade span **112**, such as between about thirty percent of the fan blade span **112** and about forty percent of the fan blade span **112**.

[0053] Reference will now also be made to FIG. 3, providing an axial view of the inlet **60** to the turbofan engine **10** of FIGS. 1 and 2. As will be appreciated, the plurality of part span inlet guide vanes **100** of the turbofan engine **10** includes a relatively large number of part span inlet guide vanes **100**. For example, for the embodiment depicted, the plurality of part span inlet guide vanes **100** of the turbofan engine **10** includes thirty-two part span inlet guide vanes **100**. In other exemplary embodiments, it is contemplated that the plurality of part span inlet guide vanes **100** includes between about ten part span inlet guide vanes **100** and about fifty part span inlet guide vanes **100**. In further exemplary embodiments, it is contemplated that the plurality of part span inlet guide vanes **100** includes between about twenty part span inlet guide vanes **100** and about forty-five part span inlet guide vanes **100**. Additionally, for the embodiment depicted, each of the plurality of part span inlet guide vanes **100** are spaced substantially evenly (e.g., equidistant) along the circumferential direction C. More specifically, each of the plurality of part span inlet guide vanes **100** defines a circumferential spacing **118** with an adjacent part span inlet guide vane **100**, with the circumferential spacing **118** being substantially equal between each adjacent part span inlet guide vane **100**.

[0054] Although not depicted, in certain exemplary embodiments, the number of part span inlet guide vanes **100** may be substantially equal to the number of fan blades **40** (FIG. 1) of the fan **38** (FIG. 1) of the turbofan engine **10**. In other embodiments, however, the number of part span inlet guide vanes **100** may be greater than the number of fan blades **40** of the fan **38** of the turbofan engine **10**, or alternatively, may be less than the number of fan blades **40** of the fan **38** of the

turbofan engine **10**.

[0055] Further, it should be appreciated, that in other exemplary embodiments, the turbofan engine **10** may include any other suitable number of part span inlet guide vanes **100** and/or circumferential spacing **118** of the part span inlet guide vanes **100**. For example, referring now briefly to FIG. **4**, an axial view of an inlet **60** to a turbofan engine **10** in accordance with another exemplary embodiment of the present disclosure is provided. For the embodiment of FIG. **4**, the turbofan engine **10** includes less than twenty part span inlet guide vanes **100**. More specifically, for the embodiment of FIG. **4**, the turbofan engine **10** includes at least eight part span inlet guide vanes **100**, or more specifically includes exactly eight part span inlet guide vanes **100**. Additionally, for the embodiment of FIG. **4**, the plurality of part span inlet guide vanes **100** are not substantially evenly spaced along the circumferential direction C. For example, at least certain of the plurality of part span inlet guide vanes **100** define a first circumferential spacing **118A**, while other of the plurality of part span inlet guide vanes **100** define a second circumferential spacing **118B**. For the embodiment depicted, the first circumferential spacing **118A** is at least about twenty percent greater than the second circumferential spacing **118B**, such as at least about twenty-five percent greater such as at least about thirty percent greater, such as up to about two hundred percent greater. Notably, the circumferential spacing **118** refers to a mean circumferential spacing between adjacent part span inlet guide vanes **100**. The non-uniform circumferential spacing may, e.g., offset structure upstream of the part span inlet guide vanes **100**.

[0056] Referring back to FIG. **3**, the outer nacelle **50** defines a radius NR. For the embodiment depicted, the plurality of part span inlet guide vanes **100** are angled (e.g., tilted) at a first angle A1 with respect to the radius NR of the outer nacelle **50**.

[0057] In this manner, the plurality of part span inlet guide vanes **100** are configured to direct incoming objects towards an outer radial portion of the turbofan engine **10** (FIG. **1**). The plurality of part span inlet guide vanes **100** are configured to direct incoming objects away from the core air flowpath **37** (FIG. **1**) of the turbofan engine **10** and towards a bypass airflow passage **56** (FIG. **1**). This provides a deflection mechanism that facilitates ingestion of an object into an outer radial portion of the turbofan engine **10** (FIG. **1**) and thereby minimizing the chance that the object travels to the core of the turbofan engine **10**.

[0058] Furthermore, in this manner, the plurality of part span inlet guide vanes **100** are also configured to pre-swirl an airflow **58** (FIG. **1**) provided through the inlet **60** of the outer nacelle **50**, upstream of the plurality of fan blades **40** (FIG. **1**) of the fan **38** (FIG. **1**). As discussed herein, pre-swirling the airflow **58** provided through the inlet **60** of the nacelle **50** prior to such airflow **58** reaching the plurality of fan blades **40** of the fan **38** may reduce separation losses and/or shock losses, allowing the fan **38** to operate with the relatively high fan tip speeds described above with less losses in efficiency. Furthermore, in this manner, the plurality of part span inlet guide vanes **100** are also configured to minimize flutter and maintain laminar air flow over the part span inlet guide vanes **100** and minimize turbulence in the inlet **60**.

[0059] In certain exemplary embodiments, the first angle A1 is between approximately 2 degrees and approximately 45 degrees. In other exemplary embodiments, it is contemplated that the first angle A1 is between other ranges for a particular application.

[0060] In the exemplary embodiment depicted in FIG. **3**, the plurality of part span inlet guide vanes **100** are angled at the first angle A1 with respect to the radius NR of the outer nacelle **50** in a clockwise direction CW, i.e., the same direction that the fan blades **40** (FIG. **2**) rotate in.

[0061] In an exemplary embodiment, the plurality of part span inlet guide vanes **100** are each angled at the same first angle A1 with respect to the radius NR of the outer nacelle **50**. In other exemplary embodiments, the plurality of part span inlet guide vanes **100** are angled at different first angles A1 with respect to the radius NR of the outer nacelle **50** as will be described in more detail below.

[0062] Referring now to FIG. **5**, an axial view of the inlet **60** to the turbofan engine **10** of FIGS. **1**

and 2, according to another exemplary embodiment, is provided. Referring to FIG. 5, in another exemplary embodiment, the plurality of part span inlet guide vanes **100** are angled at the first angle **A1** with respect to the radius **NR** of the outer nacelle **50** in a counterclockwise direction **CCW**, i.e., the opposite direction that the fan blades **40** (FIG. 2) rotate in.

[0063] Referring now back to FIG. 2, as described above, each of the plurality of part span inlet guide vanes **100** are configured to pre-swirl an airflow **58** provided through the inlet **60** of the nacelle **50**, upstream of the plurality of fan blades **40** of the fan **38**. As discussed above, pre-swirling the airflow **58** provided through the inlet **60** of the nacelle **50** prior to such airflow **58** reaching the plurality of fan blades **40** of the fan **38** may reduce separation losses and/or shock losses, allowing the fan **38** to operate with the relatively high fan tip speeds described above with less losses of in efficiency.

[0064] For example, referring first to FIG. 6, a cross-sectional view of one part span inlet guide vane **100** along the span of the part span inlet guide vanes **100**, as indicated by Line **6-6** in FIG. 2, is provided. As is depicted, the part span inlet guide vane **100** is configured generally as an airfoil having a pressure side **120** and an opposite suction side **122**, and extending between the leading edge **108** and the trailing edge **110** along a camber line **124**. Additionally, the part span inlet guide vane **100** defines a chord line **126** extending directly from the leading edge **108** to the trailing edge **110**. The chord line **126** of the part span inlet guide vane **100** is angled (e.g., twisted) at a second angle or angle of attack **128** with respect to the longitudinal axis **12** of the outer nacelle **50** (FIG. 2). For example, the chord line **126** defines a second angle or angle of attack **128** with an airflow direction **129** of the airflow **58** through the inlet **60** (FIG. 2) of the nacelle **50**. Notably, for the embodiment depicted, the airflow direction **129** is substantially parallel to the axial direction **A** and the longitudinal axis **12** of the outer nacelle **50** of the turbofan engine **10**. For the embodiment depicted, the angle of attack **128** at the location depicted along the span **106** of the part span inlet guide vanes **100** is at least approximately five degrees and up to approximately thirty-five degrees. For example, in certain embodiments, the angle of attack **128** at the location depicted along the span **106** of the part span inlet guide vane **100** may be between about ten degrees and about thirty degrees, such as between about fifteen degrees and about twenty-five degrees.

[0065] Additionally, the part span inlet guide vane **100**, at the location depicted along the span **106** (FIG. 2) of the part span inlet guide vane **100** defines a local swirl angle **130** at the trailing edge **110**. The “swirl angle” at the trailing edge **110** of the part span inlet guide vane **100**, as used herein, refers to an angle between the airflow direction **129** of the airflow **58** through the inlet **60** (FIG. 2) of the nacelle **50** (FIG. 2) and a reference line **132** defined by a trailing edge section of the pressure side **120** of the part span inlet guide vane **100**. More specifically, the reference line **132** is defined by the aft twenty percent of the pressure side **120**, as measured along the chord line **126**. Notably, when the aft twenty percent the pressure side **120** defines a curve, the reference line **132** may be a straight-line average fit of such curve (e.g., using least mean squares).

[0066] Further, it will be appreciated, that a maximum swirl angle **130** refers to the highest swirl angle **130** along the span **106** (FIG. 2) of the part span inlet guide vane **100**. For the embodiment depicted, the maximum swirl angle **130** is defined proximate the radially outer end **102** (FIG. 2) of the part span inlet guide vane **100** (e.g., at the outer ten percent of the span **106** of the part span inlet guide vanes **100**), as is represented by the cross-section depicted in FIG. 6. For the embodiment depicted, the maximum swirl angle **130** of each part span inlet guide vane **100** at the trailing edge **110** is between approximately five degrees and approximately thirty-five degrees. For example, in certain exemplary embodiments, the maximum swirl angle **130** of each part span inlet guide vane **100** at the trailing edge **110** may be between twelve degrees and twenty-five degrees.

[0067] Moreover, it should be appreciated that for the embodiment of FIG. 2, the local swirl angle **130** increases from the radially inner end **104** (FIG. 2) to the radially outer end **102** (FIG. 2) of each part span inlet guide vane **100**. For example, referring now also to FIG. 7, a cross-sectional view of a part span inlet guide vane **100** at a location radially inward from the cross-section viewed in FIG.

6, as indicated by Line 7-7 in FIG. 2, is provided. As is depicted in FIG. 7, and as stated above, the part span inlet guide vane **100** defines the pressure side **120**, the suction side **122**, the leading edge **108**, the trailing edge **110**, the camber line **124**, and chord line **126**. Further, the second angle or angle of attack **128** defined by the chord line **126** and the airflow direction **129** of the airflow **58** through the inlet **60** of the nacelle **50** at the location along the span **106** depicted in FIG. 7 is less than the angle of attack **128** at the location along the span **106** depicted in FIG. 6 (e.g., may be at least about twenty percent less, such as at least about fifty percent less, such as up to about one hundred percent less). Additionally, the part span inlet guide vane **100** defines a local swirl angle **130** at the trailing edge **110** at the location along the span **106** of the part span inlet guide vane **100** proximate the inner end **104**, as depicted in FIG. 7. As stated above, the local swirl angle **130** increases from the radially inner end **104** to the radially outer end **102** of each part span inlet guide vanes **100**. Accordingly, the local swirl angle **130** proximate the outer end **102** (see FIG. 6) is greater than the local swirl angle **130** proximate the radially inner end **104** (see FIG. 7; e.g., the radially inner ten percent of the span **106**). For example, the local swirl angle **130** may approach zero degrees (e.g., may be less than about five degrees, such as less than about two degrees) at the radially inner end **104**.

[0068] Notably, including part span inlet guide vanes **100** of such a configuration may reduce an amount of turbulence at the radially inner end **104** (FIG. 2) of each respective part span inlet guide vane **100**. Additionally, such a configuration may provide a desired amount of pre-swirl at the radially outer ends of the plurality of fan blades **40** (FIG. 2) of the fan **38** (FIG. 2) (where the speed of the fan blades **40** is the greatest) to provide a desired reduction in flow separation and/or shock losses that may otherwise occur due to a relatively high speed of the plurality of fan blades **40** at the fan tips during operation of the turbofan engine **10** (FIG. 2).

[0069] Referring now to FIG. 8, an axial view of the inlet **60** to the turbofan engine **10** of FIGS. 1 and 2, according to another exemplary embodiment, is provided. Referring to FIG. 8, in another exemplary embodiment, the plurality of part span inlet guide vanes **100** are angled at different first angles **A1** with respect to the radius **NR** of the outer nacelle **50**.

[0070] The outer nacelle **50** includes a top portion **210**, a bottom portion **212**, a first side portion **214**, and a second side portion **216**. In an exemplary embodiment, a first portion, e.g., the top portion **210**, of the part span inlet guide vanes **100** are angled at a first angle **A1** with respect to the radius **NR** of the outer nacelle **50**. For example, the part span inlet guide vanes **100** are angled at a first angle **A1** of five degrees or seven degrees with respect to the radius **NR** of the outer nacelle **50** at the top portion **210**. Furthermore, a second portion, e.g., the first side portion **214**, of the part span inlet guide vanes **100** are angled at a different angle with respect to the radius **NR** of the outer nacelle **50**. For example, the part span inlet guide vanes **100** are angled at a first angle **A1** of ten degrees or fifteen degrees with respect to the radius **NR** of the outer nacelle **50** at the first side portion **214**. In such exemplary embodiments, the plurality of part span inlet guide vanes **100** are angled at different first angles **A1** with respect to the radius **NR** of the outer nacelle **50** along the circumferential direction **C**.

[0071] In such an exemplary embodiment, circumferential variation in the angle of tilt, e.g., the first angle **A1** with respect to the radius **NR** of the outer nacelle **50**, can address many issues including cross winds, high angle of attack maneuvers such as takeoff, and engine installation on one side of an aircraft or another. For example, cross winds are more likely to affect the 3 or 9 o'clock positions on the engine, e.g., the second side portion **216** and the first side portion **214**, which may make a different angle of tilt more desirable at the 3/9 o'clock positions than at the 6/12 o'clock positions on the engine, e.g., the bottom portion **212** and the top portion **210**. In addition, installation on one side of the aircraft or the other may make cross wind effects more pronounced on the side of the engine that is further from the fuselage. Likewise, a high angle of attack may make differing tilt angles at the 6/12 o'clock positions desirable, e.g., the bottom portion **212** and the top portion **210**. For these reasons, it is contemplated that the first angles **A1** with respect to the

radius NR of the outer nacelle **50** may vary for a particular application and may be different at the top portion **210**, the bottom portion **212**, the first side portion **214**, and/or the second side portion **216** of the outer nacelle **50**.

[0072] Referring now to FIG. **9**, an axial view of the inlet **60** to the turbofan engine **10** of FIGS. **1** and **2**, according to another exemplary embodiment, is provided. Referring to FIG. **9**, in another exemplary embodiment, the plurality of part span inlet guide vanes **100** are angled at different first angles **A1** with respect to the radius NR of the outer nacelle **50**.

[0073] The outer nacelle **50** includes a top portion **210**, a bottom portion **212**, a first side portion **214**, and a second side portion **216**. In an exemplary embodiment, the part span inlet guide vanes **100** are angled at different first angles **A1** with respect to the radius NR of the outer nacelle **50** at the top portion **210** and the bottom portion **212**. For example, the top portion **210** of the part span inlet guide vanes **100** are angled at a first angle **A1** with respect to the radius NR of the outer nacelle **50**. For example, the part span inlet guide vanes **100** are angled at a first angle **A1** of five degrees or seven degrees with respect to the radius NR of the outer nacelle **50** at the top portion **210**. Furthermore, the bottom portion **212** of the part span inlet guide vanes **100** are angled at a different angle with respect to the radius NR of the outer nacelle **50**. For example, the part span inlet guide vanes **100** are angled at a first angle **A1** of ten degrees with respect to the radius NR of the outer nacelle **50** at the bottom portion **212**. In such exemplary embodiments, the plurality of part span inlet guide vanes **100** are angled at different first angles **A1** with respect to the radius NR of the outer nacelle **50** at the top portion **210** and the bottom portion **212**.

[0074] In such an exemplary embodiment, circumferential variation in the angle of tilt, e.g., the first angle **A1** with respect to the radius NR of the outer nacelle **50**, can address many issues including cross winds, high angle of attack maneuvers such as takeoff, and engine installation on one side of an aircraft or another. For example, cross winds are more likely to affect the 3 or 9 o'clock positions on the engine, e.g., the second side portion **216** and the first side portion **214**, which may make a different angle of tilt more desirable at the 3/9 o'clock positions than at the 6/12 o'clock positions on the engine, e.g., the bottom portion **212** and the top portion **210**. In addition, installation on one side of the aircraft or the other may make cross wind effects more pronounced on the side of the engine that is further from the fuselage. Likewise, a high angle of attack may make differing tilt angles at the 6/12 o'clock positions desirable, e.g., the bottom portion **212** and the top portion **210**. For these reasons, it is contemplated that the first angles **A1** with respect to the radius NR of the outer nacelle **50** may vary for a particular application and may be different at the top portion **210**, the bottom portion **212**, the first side portion **214**, and/or the second side portion **216** of the outer nacelle **50**.

[0075] Referring now to FIG. **10**, an axial view of the inlet **60** to the turbofan engine **10** of FIGS. **1** and **2**, according to another exemplary embodiment, is provided. Referring to FIG. **10**, in another exemplary embodiment, one of the part span inlet guide vanes **100** are angled at different angles with respect to the radius NR of the outer nacelle **50** at different portions of the part span inlet guide vane **100**.

[0076] For example, the part span inlet guide vane **100** is angled at a first angle **A1** with respect to the radius NR of the outer nacelle **50** a first location **250** of the part span inlet guide vane **100** and the part span inlet guide vane **100** is angled at a second angle **A2** with respect to the radius NR of the outer nacelle **50** at a second location **252** of the part span inlet guide vane **100**. In such an embodiment, the first angle **A1** is different than the second angle **A2**. For example, in the embodiment depicted in FIG. **10**, the first angle **A1** is greater than the second angle **A2**.

[0077] In such an exemplary embodiment, varying the angle of tilt, e.g., the first angle **A1** and the second angle **A2**, from the base of the part span inlet guide vane **100**, e.g., the outer end **102** (FIG. **2**), to the tip of the part span inlet guide vane **100**, e.g., the inner end **104** (FIG. **2**), can address varying levels of turbulence due to boundary layer effects, as you get closer to/further from the wall **52** (FIG. **2**) of the outer nacelle **50**. The angle of tilt and sweep may also be used to improve

the matching of the swirl that is imparted to the incoming air with the varying linear speed of the fan blade **40** (FIG. 2) as you get closer to/further from the axis **12** (FIG. 1) of the engine **10**. The linear speed of the fan blade **40** (FIG. 2) is greatest at the tip, and slowest at the root of the fan blade **40** (FIG. 2), even though the rotational velocity is equal.

[0078] Referring now to FIG. 11, an axial view of the inlet **60** to the turbofan engine **10** of FIGS. 1 and 2, according to another exemplary embodiment, is provided. Referring to FIG. 11, in another exemplary embodiment, one of the part span inlet guide vanes **100** are angled at different angles with respect to the radius NR of the outer nacelle **50** at different locations of the part span inlet guide vane **100**.

[0079] For example, the part span inlet guide vane **100** is angled at a first angle A1 with respect to the radius NR of the outer nacelle **50** a first location **250** of the part span inlet guide vane **100** and the part span inlet guide vane **100** is angled at a second angle A2 with respect to the radius NR of the outer nacelle **50** at a second location **252** of the part span inlet guide vane **100**. In such an embodiment, the first angle A1 is different than the second angle A2. For example, in the embodiment depicted in FIG. 11, the first angle A1 is less than the second angle A2.

[0080] In such an exemplary embodiment, varying the angle of tilt, e.g., the first angle A1 and the second angle A2, from the base of the part span inlet guide vane **100**, e.g., the outer end **102** (FIG. 2), to the tip of the part span inlet guide vane **100**, e.g., the inner end **104** (FIG. 2), can address varying levels of turbulence due to boundary layer effects, as you get closer to/further from the wall **52** (FIG. 2) of the outer nacelle **50**. The angle of tilt and sweep may also be used to improve the matching of the swirl that is imparted to the incoming air with the varying linear speed of the fan blade **40** (FIG. 2) as you get closer to/further from the axis **12** (FIG. 1) of the engine **10**. The linear speed of the fan blade **40** (FIG. 2) is greatest at the tip, and slowest at the root of the fan blade **40** (FIG. 2), even though the rotational velocity is equal.

[0081] Further aspects of the disclosure are provided by the subject matter of the following clauses:

[0082] A turbofan engine comprising: a fan comprising a plurality of fan blades; a turbomachine operably coupled to the fan for driving the fan, the turbomachine comprising a compressor section, a combustion section, and a turbine section in serial flow order and together defining a core air flowpath; a nacelle surrounding and at least partially enclosing the fan, the nacelle defining a radius and a longitudinal axis; and an inlet pre-swirl vane located upstream of the plurality of fan blades and defining a chord, the inlet pre-swirl vane coupled to the nacelle, wherein the inlet pre-swirl vane is angled at a first angle with respect to the radius of the nacelle, and wherein the chord of the inlet pre-swirl vane is angled at a second angle with respect to the longitudinal axis of the nacelle.

[0083] The turbofan engine of any preceding clause, wherein the inlet pre-swirl vane is angled at the first angle with respect to the radius of the nacelle in a clockwise direction from an inlet of the nacelle.

[0084] The turbofan engine of any preceding clause, wherein the inlet pre-swirl vane is angled at the first angle with respect to the radius of the nacelle in a counterclockwise direction from an inlet of the nacelle.

[0085] The turbofan engine of any preceding clause, wherein the first angle is between approximately 2 degrees and approximately 45 degrees.

[0086] The turbofan engine of any preceding clause, wherein the second angle is between approximately 5 degrees and approximately 35 degrees.

[0087] The turbofan engine of any preceding clause, wherein the inlet pre-swirl vane is one of a plurality of part span inlet guide vanes extending from the nacelle upstream of the plurality of fan blades and aft of an inlet of the nacelle.

[0088] The turbofan engine of any preceding clause, wherein each of the plurality of part span inlet guide vanes is angled at the same first angle with respect to the radius of the nacelle.

[0089] The turbofan engine of any preceding clause, wherein a first portion of each of the plurality of part span inlet guide vanes is angled at the first angle with respect to the radius of the nacelle,

wherein a second portion of each of the plurality of part span inlet guide vanes is angled at a third angle with respect to the radius of the nacelle, and wherein the first angle is different than the third angle.

[0090] The turbofan engine of any preceding clause, wherein the nacelle includes a top portion, a bottom portion, a first side portion, and a second side portion, wherein a first portion of each of the plurality of part span inlet guide vanes is angled at the first angle with respect to the radius of the nacelle at the top portion, wherein a second portion of each of the plurality of part span inlet guide vanes is angled at a third angle with respect to the radius of the nacelle at the bottom portion, and wherein the first angle is different than the third angle.

[0091] A nacelle assembly for a turbofan engine, the turbofan engine comprising a fan including a plurality of fan blades, the nacelle assembly comprising: a nacelle surrounding and at least partially enclosing the fan, the nacelle defining a radius and a longitudinal axis; and an inlet pre-swirl vane located upstream of the plurality of fan blades and defining a chord, the inlet pre-swirl vane coupled to the nacelle, wherein the inlet pre-swirl vane is angled at a first angle with respect to the radius of the nacelle, and wherein the chord of the inlet pre-swirl vane is angled at a second angle with respect to the longitudinal axis of the nacelle.

[0092] The nacelle assembly of any preceding clause, wherein the inlet pre-swirl vane is angled at the first angle with respect to the radius of the nacelle in a clockwise direction from an inlet of the nacelle.

[0093] The nacelle assembly of any preceding clause, wherein the inlet pre-swirl vane is angled at the first angle with respect to the radius of the nacelle in a counterclockwise direction from an inlet of the nacelle.

[0094] The nacelle assembly of any preceding clause, wherein the first angle is between approximately 2 degrees and approximately 45 degrees.

[0095] The nacelle assembly of any preceding clause, wherein the second angle is between approximately 5 degrees and approximately 35 degrees.

[0096] The nacelle assembly of any preceding clause, wherein the inlet pre-swirl vane is one of a plurality of part span inlet guide vanes extending from the nacelle upstream of the plurality of fan blades and aft of an inlet of the nacelle.

[0097] The nacelle assembly of any preceding clause, wherein each of the plurality of part span inlet guide vanes is angled at the same first angle with respect to the radius of the nacelle.

[0098] The nacelle assembly of any preceding clause, wherein a first portion of each of the plurality of part span inlet guide vanes is angled at the first angle with respect to the radius of the nacelle, wherein a second portion of each of the plurality of part span inlet guide vanes is angled at a third angle with respect to the radius of the nacelle, and wherein the first angle is different than the third angle.

[0099] The nacelle assembly of any preceding clause, wherein the nacelle includes a top portion, a bottom portion, a first side portion, and a second side portion, wherein a first portion of each of the plurality of part span inlet guide vanes is angled at the first angle with respect to the radius of the nacelle at the top portion, wherein a second portion of each of the plurality of part span inlet guide vanes is angled at a third angle with respect to the radius of the nacelle at the bottom portion, and wherein the first angle is different than the third angle.

[0100] A nacelle assembly for a turbofan engine, the turbofan engine comprising a fan including a plurality of fan blades, the nacelle assembly comprising: a nacelle surrounding and at least partially enclosing the fan, the nacelle defining a radius; and an inlet pre-swirl vane located upstream of the plurality of fan blades, the inlet pre-swirl vane coupled to the nacelle, wherein the inlet pre-swirl vane is angled at a first angle with respect to the radius of the nacelle at a first location of the inlet pre-swirl vane, wherein the inlet pre-swirl vane is angled at a second angle with respect to the radius of the nacelle at a second location of the inlet pre-swirl vane, and wherein the first angle is different than the second angle.

[0101] The nacelle assembly of any preceding clause, wherein the nacelle defines a longitudinal axis, wherein the inlet pre-swirl vane defines a chord, and wherein the chord of the inlet pre-swirl vane is angled at a third angle with respect to the longitudinal axis of the nacelle.

[0102] This written description uses examples to disclose the disclosure, including the best mode, and also to enable any person skilled in the art to practice the disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope 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 include 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.

[0103] While this disclosure has been described as having exemplary designs, the present disclosure can be further modified within the scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the disclosure using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this disclosure pertains and which fall within the limits of the appended claims.

Claims

1. A turbofan engine comprising: a fan comprising a plurality of fan blades; a turbomachine operably coupled to the fan for driving the fan, the turbomachine comprising a compressor section, a combustion section, and a turbine section in serial flow order and together defining a core air flowpath; a nacelle surrounding and at least partially enclosing the fan, the nacelle defining a radius, a longitudinal axis, and a circumferential direction extending about the longitudinal axis; and an inlet pre-swirl vane located upstream of the plurality of fan blades and defining a chord, the inlet pre-swirl vane coupled to the nacelle, wherein the inlet pre-swirl vane is angled at a first angle with respect to the radius of the nacelle, and wherein the chord of the inlet pre-swirl vane is angled at a second angle with respect to the longitudinal axis of the nacelle, wherein the inlet pre-swirl vane is one of a plurality of part span inlet guide vanes extending from the nacelle upstream of the plurality of fan blades and aft of an inlet of the nacelle, wherein at least a portion of the plurality of part span inlet guide vanes are non-uniformly spaced between adjacent ones of the plurality of part span inlet guide vanes in the circumferential direction.
2. The turbofan engine of claim 1, wherein the plurality of part span inlet guide vanes comprises a first part span inlet guide vane located adjacent a second part span inlet guide vane and a third part span inlet guide vane located adjacent the second part span inlet guide vane, and wherein a first circumferential spacing is defined between the first and second part span inlet guide vanes in the circumferential direction, and wherein a second circumferential spacing is defined between the second and third part span inlet guide vanes in the circumferential direction, wherein the first circumferential spacing is different than the second circumferential spacing.
3. The turbofan engine of claim 2, wherein the first circumferential spacing is at least twenty percent greater than the second circumferential spacing.
4. The turbofan engine of claim 2, wherein the first circumferential spacing is at least twenty-five percent greater than the second circumferential spacing.
5. The turbofan engine of claim 2, wherein the first circumferential spacing is at least thirty percent greater than the second circumferential spacing.
6. The turbofan engine of claim 1, wherein the plurality of part span inlet guide vanes includes a first portion and a second portion, wherein the first portion of the plurality of part span inlet guide vanes are angled at the first angle with respect to the radius of the nacelle, and wherein the second portion of the plurality of part span inlet guide vanes are angled at a third angle with respect to the

radius of the nacelle, wherein the first angle is different than the third angle.

7. The turbofan engine of claim 1, wherein the inlet pre-swirl vane is angled at the first angle with respect to the radius of the nacelle in a clockwise direction from an inlet of the nacelle.

8. The turbofan engine of claim 1, wherein the inlet pre-swirl vane is angled at the first angle with respect to the radius of the nacelle in a counterclockwise direction from an inlet of the nacelle.

9. A nacelle assembly for a turbofan engine, the turbofan engine comprising a fan including a plurality of fan blades, the nacelle assembly comprising: a nacelle surrounding and at least partially enclosing the fan, the nacelle defining a radius, a longitudinal axis, and a circumferential direction extending about the longitudinal axis; and an inlet pre-swirl vane located upstream of the plurality of fan blades and defining a chord, the inlet pre-swirl vane coupled to the nacelle, wherein the inlet pre-swirl vane is angled at a first angle with respect to the radius of the nacelle, and wherein the chord of the inlet pre-swirl vane is angled at a second angle with respect to the longitudinal axis of the nacelle, wherein the inlet pre-swirl vane is one of a plurality of part span inlet guide vanes extending from the nacelle upstream of the plurality of fan blades and aft of an inlet of the nacelle, wherein at least a portion of the plurality of part span inlet guide vanes are non-uniformly spaced between adjacent ones of the plurality of part span inlet guide vanes in the circumferential direction.

10. The nacelle assembly of claim 9, wherein the plurality of part span inlet guide vanes comprises a first part span inlet guide vane located adjacent a second part span inlet guide vane and a third part span inlet guide vane located adjacent the second part span inlet guide vane, and wherein a first circumferential spacing is defined between the first and second part span inlet guide vanes in the circumferential direction, and wherein a second circumferential spacing is defined between the second and third part span inlet guide vanes in the circumferential direction, wherein the first circumferential spacing is different than the second circumferential spacing.

11. The nacelle assembly of claim 10, wherein the first circumferential spacing is at least twenty percent greater than the second circumferential spacing.

12. The nacelle assembly of claim 10, wherein the first circumferential spacing is at least twenty-five percent greater than the second circumferential spacing.

13. The nacelle assembly of claim 10, wherein the first circumferential spacing is at least thirty percent greater than the second circumferential spacing.

14. The nacelle assembly of claim 9, wherein the plurality of part span inlet guide vanes includes a first portion and a second portion, wherein the first portion of the plurality of part span inlet guide vanes are angled at the first angle with respect to the radius of the nacelle, and wherein the second portion of the plurality of part span inlet guide vanes are angled at a third angle with respect to the radius of the nacelle, wherein the first angle is different than the third angle.

15. The nacelle assembly of claim 9, wherein the inlet pre-swirl vane is angled at the first angle with respect to the radius of the nacelle in a clockwise direction from an inlet of the nacelle.

16. The nacelle assembly of claim 9, wherein the inlet pre-swirl vane is angled at the first angle with respect to the radius of the nacelle in a counterclockwise direction from an inlet of the nacelle.

17. A turbofan engine comprising: a fan comprising a plurality of fan blades; a turbomachine operably coupled to the fan for driving the fan, the turbomachine comprising a compressor section, a combustion section, and a turbine section in serial flow order and together defining a core air flowpath; a nacelle surrounding and at least partially enclosing the fan, the nacelle defining a radius, a longitudinal axis, and a circumferential direction extending about the longitudinal axis; and a plurality of part span inlet guide vanes extending from the nacelle upstream of the plurality of fan blades and aft of an inlet of the nacelle, wherein at least a portion of the plurality of part span inlet guide vanes are non-uniformly spaced between adjacent ones of the plurality of part span inlet guide vanes in the circumferential direction.

18. The turbofan engine of claim 17, wherein the plurality of part span inlet guide vanes comprises a first part span inlet guide vane located adjacent a second part span inlet guide vane and a third

part span inlet guide vane located adjacent the second part span inlet guide vane, and wherein a first circumferential spacing is defined between the first and second part span inlet guide vanes in the circumferential direction, and wherein a second circumferential spacing is defined between the second and third part span inlet guide vanes in the circumferential direction, wherein the first circumferential spacing is different than the second circumferential spacing.

19. The turbofan engine of claim 18, wherein the first circumferential spacing is at least twenty percent greater than the second circumferential spacing.

20. The turbofan engine of claim 17, wherein the plurality of part span inlet guide vanes includes a first portion and a second portion, wherein the first portion of the plurality of part span inlet guide vanes are angled at a first angle with respect to the radius of the nacelle, and wherein the second portion of the plurality of part span inlet guide vanes are angled at a second angle with respect to the radius of the nacelle, wherein the first angle is different than the second angle.
