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SEAL ASSEMBLY FOR A TURBINE ENGINE

Abstract

A seal assembly includes a plurality of seal segments for sealing between a rotor and a stator, wherein, when arranged together, the rotor, the stator, and the plurality of seal segments define a high pressure region and a low pressure region. The seal assembly further includes a biasing member engaged with the plurality of seal segments and at least one feature formed in the stator. As such pressurized fluid engaging with the at least one feature provides an aft-to-forward axial force that reduces friction between interfacing aft surfaces of the plurality of seal segments and the stator.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a divisional application of U.S. application Ser. No. 18/543,591 filed Dec. 18, 2023, which is hereby incorporated by reference in its entirety.

FIELD

[0002] The present disclosure relates generally to turbine engines, and more particularly to seal assemblies for a turbine engine.

BACKGROUND

[0003] Gas turbine engines, such as turbofan engines, may be used for aircraft propulsion. A turbofan engine generally includes a bypass fan section and a turbomachine such as a gas turbine engine to drive the bypass fan. The turbomachine generally includes a compressor section, a combustion section, and a turbine section in a serial flow arrangement. Both the compressor section and the turbine section are driven by one or more rotor shafts and generally include multiple rows or stages of rotor blades coupled to the rotor shaft. Each individual row of rotor blades is axially spaced from a successive row of rotor blades by a respective row of stator or stationary vanes. A radial gap is formed between an inner surface of the stator vanes and an outer surface of the rotor shaft. Gas turbine engines may further include various seals to reduce and/or block flow (e.g., working fluid flow) leakage between various components of the gas engine.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] A full and enabling disclosure, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which refers to the appended Figures, in which:

[0005] FIG. 1 is a cross-sectional view of a gas turbine engine in accordance with an aspect of the present disclosure.

[0006] FIG. 2 is a cross sectional, schematic view of a portion of the turbomachine of FIG. 1.

[0007] FIG. 3 is a close-up, schematic, cross-sectional view of a portion of the turbomachine of FIG. 2, taken along line 3-3.

[0008] FIG. 4 is a close-up, schematic, cross-sectional view of the rotor, stator, carrier, and seal assembly of FIG. 3, particularly illustrating an aerodynamic seal assembly.

[0009] FIG. 5 is a close-up, schematic, cross-sectional view of another embodiment of a rotor, stator, carrier, and seal assembly of a turbomachine in accordance with an aspect of the present disclosure, particularly illustrating an aerodynamic seal assembly.

[0010] FIG. 6 is a close-up, schematic, cross-sectional view of still another embodiment of a rotor, stator, carrier, and seal assembly of a turbomachine in accordance with an aspect of the present disclosure, particularly illustrating an aerodynamic seal assembly.

[0011] FIG. 7 is a close-up, schematic, cross-sectional view of yet another embodiment of a rotor, stator, carrier, and seal assembly of a turbomachine in accordance with an aspect of the present disclosure, particularly illustrating an aerostatic seal assembly.

DETAILED DESCRIPTION

[0012] 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.

[0013] The singular forms “a”, “an”, and “the” include plural references unless the context clearly dictates otherwise.

[0014] The term “at least one of” in the context of, e.g., “at least one of A, B, and C” refers to only A, only B, only C, or any combination of A, B, and C.

[0015] The term “turbomachine” refers to a machine including one or more compressors, a heat generating section (e.g., a combustion section), and one or more turbines that together generate a torque output.

[0016] The term “gas turbine engine” or “turbine engine” refers to an engine having a turbomachine as all or a portion of its power source. Example gas turbine engines include turbofan engines, turboprop engines, turbojet engines, turboshaft engines, etc., as well as hybrid-electric versions of one or more of these engines.

[0017] The term “combustion section” refers to any heat addition system for a turbomachine. For example, the term combustion section may refer to a section including one or more of a deflagrative combustion assembly, a rotating detonation combustion assembly, a pulse detonation combustion assembly, or other appropriate heat addition assembly. In certain example embodiments, the combustion section may include an annular combustor, a can combustor, a cannular combustor, a trapped vortex combustor (TV C), or other appropriate combustion system, or combinations thereof.

[0018] The terms “low” and “high”, or their respective comparative degrees (e.g., -er, where applicable), when used with a compressor, a turbine, a shaft, or spool components, etc. each refer to relative speeds within an engine unless otherwise specified. For example, a “low turbine” or “low speed turbine” defines a component configured to operate at a rotational speed, such as a maximum allowable rotational speed, lower than a “high turbine” or “high speed turbine” of the engine.

[0019] The terms “forward” and “aft” refer to relative positions within a gas turbine engine or vehicle. For example, with regard to a gas turbine engine, forward refers to a position closer to an engine inlet and aft refers to a position closer to an engine nozzle or exhaust.

[0020] 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.

[0021] The term “proximate” refers to being closer to one end than an opposite end. For example, when used in conjunction with first and second ends; high-pressure and low-pressure sides; or the like, the phrase “proximate the first end,” or “proximate the high-pressure side,” refers to a location closer to the first end than the second end, or closer to the high-pressure side than the low-pressure side, respectively.

[0022] The term “adjacent” with respect to a relative position of two like components refers to there being no other like components positioned therebetween. The term “adjacent” with respect to a relative position of two different components refers to there being no intervening structure separating the two components.

[0023] An “aerodynamic seal” generally refers to a mechanical seal that uses a dynamic rotor and one or more grooves on the rotor or stator that create an air film that the opposing sealing surface rides on. An “aerostatic seal” generally refers to a mechanical seal that uses air from the high-pressure region routed via one or more feed ports (or aerostatic ports) to create an air film between the sealing surface and the opposing rotor. A “hybrid seal” generally refers to a combination of an aerodynamic seal with at least one groove and an aerostatic seal with one or more feed ports to route air from the high-pressure region.

[0024] The present disclosure is generally related to a seal assembly having a plurality of seal segments for a turbomachine of a gas turbine engine. A turbomachine generally includes a compressor section including a low-pressure compressor and a high-pressure compressor, a combustion section, and a turbine section including a high-pressure turbine and a low-pressure turbine arranged in serial-flow order. Each of the low-pressure compressor, the high-pressure compressor, the high-pressure turbine, and the low-pressure turbine include sequential rows of stationary or stator vanes axially spaced by sequential rows of rotor blades. The rotor blades are

generally coupled to a rotor shaft and the stator vanes are mounted circumferentially in a ring configuration about an outer surface of the rotor shaft. Radial gaps are formed between the outer surface of the rotor shaft and an inner portion of each ring or row of stator vanes. Radial gaps can also be formed between the outer surface of the rotor shaft, and an inner portion of a non-rotating stationary part of the engine.

[0025] During operation, it is desirable to control (reduce or prevent) compressed air flow or combustion gas flow leakage through these radial gaps. As such, a seal assembly having a plurality of seal segments is used to seal these radial gaps. More specifically, the seal segments may be disposed between the rotor and the stator. In particular, the rotor, the stator, and the seal segments are arranged together to define a high pressure region and a low pressure region. The segmented seal can be either aerodynamic seal, an aerostatic seal, or a hybrid seal. A spring is engaged with the plurality of seal segments for urging and the seal segments towards the rotor. The stator has at least one feature formed therein. Thus, pressurized fluid engaging with the feature(s) provides an aft-to-forward axial force that reduces friction between interfacing aft surfaces of the seal segments and the stator.

[0026] In an embodiment, for example, the feature(s) may be a recess formed in a surface of the stator that creates an intermediate pressure region between the high pressure region and the low pressure region. In such embodiments, the pressurized fluid in the intermediate pressure region provides the aft-to-forward axial force that minimizes the friction between the interfacing aft surfaces of the seal segments and the stator. In alternative embodiments, the feature(s) may include at least one fluid channel formed in the stator. In such embodiments, the fluid channel(s) fluidly connects high pressure fluid in the high pressure region to the interfacing aft surfaces of the seal ring and the stator to provide the aft-to-forward axial force that minimizes the friction between the interfacing aft surfaces of the seal segments and the stator.

[0027] Accordingly, the feature(s) described herein are particularly useful when the fence height (e.g., the distance between a radially outer-most surface of the rotor and a radially inner-most surface of the stator) is large. Specifically, a combination of large seal differential pressure and a large fence height can lead to large axial plug loads and an undesirable friction force interference with seal operation. Thus, the features described herein are particularly useful in addressing this issue.

[0028] 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 10 in accordance with an embodiment of the present disclosure. More particularly, for the embodiment of FIG. 1, the gas turbine engine 10 is a high-bypass turbofan jet engine, sometimes also referred to as a “turbofan engine.” As shown in FIG. 1, the gas turbine 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 C extending about the longitudinal centerline 12. In general, the gas turbine engine 10 includes a fan section 14 and a turbomachine 16 disposed downstream from the fan section 14.

[0029] The 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 booster or low-pressure (LP) compressor 22 and a high-pressure (HP) compressor 24; a combustion section 26; a turbine section including a high-pressure (HP) turbine 28 and a low-pressure (LP) turbine 30; and a jet exhaust nozzle section 32. A high-pressure (HP) shaft 34 (which may additionally or alternatively be a spool) drivingly connects the HP turbine 28 to the HP compressor 24. A low-pressure (LP) shaft 36 (which may additionally or alternatively be a spool) 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 together define a working gas flowpath 37.

[0030] For the embodiment depicted, the fan section 14 includes a fan 38 having a plurality of 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 pitch change mechanism **44** configured to collectively vary the pitch of the fan blades **40**, e.g., in unison. The gas turbine engine **10** further includes a power gear box **46**, and the fan blades **40**, disk **42**, and pitch change mechanism **44** are together rotatable about the longitudinal centerline **12** by LP shaft **36** across the power gear box **46**. The power gear box **46** includes a plurality of gears for adjusting a rotational speed of the fan **38** relative to a rotational speed of the LP shaft **36**, such that the fan **38** may rotate at a more efficient fan speed.

[0031] Referring still to the embodiment of FIG. 1, the disk **42** is covered by rotatable front hub **48** of the fan section **14** (sometimes also referred to as a “spinner”). The front hub **48** is aerodynamically contoured to promote an airflow through the plurality of fan blades **40**.

[0032] Additionally, the fan section **14** includes an annular fan casing or outer nacelle **50** that circumferentially surrounds the fan **38** and/or at least a portion of the turbomachine **16**. It should be appreciated that the outer nacelle **50** is supported relative to the turbomachine **16** by a plurality of circumferentially spaced outlet guide vanes **52** in the embodiment depicted. Moreover, a downstream section **54** of the outer nacelle **50** extends over an outer portion of the turbomachine **16** so as to define a bypass airflow passage **56** therebetween.

[0033] During operation of the gas turbine engine **10**, a volume of air **58** enters the gas turbine engine **10** through an associated inlet **60** of the outer nacelle **50** and fan section **14**. As the volume of air **58** passes across the fan blades **40**, a first portion of air **62** is directed or routed into the bypass airflow passage **56** and a second portion of air **64** as indicated by arrow **64** is directed or routed into the working gas flowpath **37**, or more specifically into the LP compressor **22**. The ratio between the first portion of air **62** and the second portion of air **64** is commonly known as a bypass ratio. A pressure of the second portion of air **64** is then increased as it is routed through the HP compressor **24** and into the combustion section **26**, where it is mixed with fuel and burned to provide combustion gases **66**.

[0034] The combustion gases **66** are routed 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**.

[0035] 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 **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 gas turbine engine **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**.

[0036] It should be appreciated, however, that the gas turbine engine **10** depicted in FIG. 1 is by way of example only, and that in other embodiments, the gas turbine engine **10** may have any other suitable configuration. For example, although the gas turbine engine **10** depicted is configured as a ducted gas turbine engine (e.g., including the outer nacelle **50**), in other embodiments, the gas turbine engine **10** may be an unducted gas turbine engine (such that the fan **38** is an unducted fan, and the outlet guide vanes **52** are cantilevered from, e.g., the outer casing **18**).

[0037] Additionally, or alternatively, although the gas turbine engine **10** depicted is configured as a

geared gas turbine engine (e.g., including the power gear box **46**) and a variable pitch gas turbine engine (e.g., including a fan **38** configured as a variable pitch fan), in other embodiments, the gas turbine engine **10** may additionally or alternatively be configured as a direct drive gas turbine engine (such that the LP shaft **36** rotates at the same speed as the fan **38**), as a fixed pitch gas turbine engine (such that the fan **38** includes fan blades **40** that are not rotatable about a pitch axis P), or both. It should also be appreciated that in still other embodiments, aspects of the present disclosure may be incorporated into any other suitable gas turbine engine. For example, in other embodiments, aspects of the present disclosure may (as appropriate) be incorporated into, e.g., a turboprop gas turbine engine, a turboshaft gas turbine engine, or a turbojet gas turbine engine.

[0038] Referring now to FIGS. **2** and **3**, various views of a portion of the turbomachine **16** of FIG. **1** are provided. In particular, FIG. **2** illustrates a cross sectional, schematic view of a portion of the turbomachine **16** of FIG. **1**. FIG. **3** illustrates a detailed, schematic cross-sectional view of a portion of the turbomachine **16** of FIG. **1**. As will be appreciated and as generally shown in FIGS. **2** and **3**, the turbomachine **16** generally includes a rotor **100**, a stator **102**, and a seal assembly **106** disposed between the rotor **100** and the stator **102**. The rotor **100** may be any rotor of the turbomachine **16**, such as the LP shaft **36**, the HP shaft **34**, etc. By way of example, referring briefly back to FIG. **1**, circles SA have been added to FIG. **1** to provide example locations that the seal assembly **106** of the present disclosure may be incorporated into a turbomachine of the present disclosure.

[0039] As shown particularly in FIG. **3**, the stator **102** further includes a stator vane **115** and the seal assembly **106** is, in the embodiment depicted, positioned at an inner end of a stator vane **115** along the radial direction R of the turbomachine **16**. The turbomachine **16** further includes a first stage **117** of rotor blades **119** and a second stage **121** of rotor blades **119** spaced along the axial direction A of the gas turbine engine **10**. The seal assembly **106** is positioned between the first stage **117** of rotor blades **119** and the second stage **121** of rotor blades **119** along the axial direction A.

[0040] In the embodiment depicted, the seal assembly **106** is positioned within a turbine section of the gas turbine engine **10**, such as within the HP turbine **28** or the LP turbine **30**. In such a manner, it will be appreciated that the rotor **100** may be a rotor coupled to the HP turbine **28**, such as the HP shaft **34**, or a rotor coupled to the LP turbine **30**, such as the LP shaft **36**. More specifically, still, in the illustrated embodiment, the rotor **100** is a connector extending between a disk **123** of the first stage **117** of rotor blades **119** and a disk **123** of the second stage **121** of rotor blades **119**. It will be appreciated, however, that in other embodiments, the seal assembly **106** may be integrated into, e.g., a compressor section of the gas turbine engine **10**.

[0041] Referring still to FIG. **2**, and as will be explained in more detail below, the seal assembly **106** includes a plurality of seal segments **108** that extend along the circumferential direction C between the rotor **100** and the stator **102**. Further, in an embodiment, as shown in FIGS. **2** and **4**, the seal assembly **106** includes a sealing face **116**. Further, as shown particularly in FIG. **4**, the rotor **100**, the stator **102**, and the plurality of seal segments **108** are arranged together to define a high pressure region **110** and a low pressure region **112**. In particular embodiments, as shown in FIG. **4**, the high pressure region **110** is located forward of the low pressure region **112**. In addition, in an embodiment, as shown, the high pressure region **110** generally includes an exterior high pressure area **138** external to the stator **102** and an interior high pressure area **140** interior of the stator **102**. As such, the seal assembly **106** is operable to prevent or minimize an airflow from the high pressure region **110** to the low pressure region **112** between the rotor **100** and the seal assembly **106**.

[0042] As will be appreciated, the seal segments **108** may be in fluid communication with a high pressure air source to provide a high pressure fluid (e.g., P.sub.HIGH) flow to the seal segments **108**. In at least certain aspects, the high pressure air source may be the working gas flowpath **37** provided through the gas turbine engine **10** and the seal assembly **106**, e.g., at the high pressure region **110** of the seal assembly **106**. In other aspects, the high-pressure air may be secondary flowpath gas sourced from a gas flow path different from the working gas flowpath **37**.

[0043] Further, as shown in FIGS. 2, 3, and 4, the seal assembly **106** includes a biasing member, such as a spring **114**, engaged with the seal segments **108**. In an embodiment, for example and as shown, the spring **114** may be a compression spring that urges contact between the seal segments **108** and the rotor **100**. In addition, as shown in FIG. 3, one or more of the seal segments **108** of the seal assembly **106** may include a groove **118** in the sealing face(s) **116** thereof. Thus, in an embodiment, the groove(s) **118** is configured to separate the sealing face(s) **116** from the primary tooth or dam **111**. One more channels **113** formed in one or more of the plurality of seal segments **108** are used to direct high pressure air from the high pressure region **110** to the groove **118**, such that the primary tooth or dam **111** acts as the seal from the high pressure region **110** to the low pressure region **112**.

[0044] More specifically, and referring to FIGS. 2, 3 and 4, the spring **114** is illustrated as a garter spring **114** that simultaneously encompasses several of the seal segments **108** but is not connected to the stator **102**. In such embodiments, as mentioned, the spring **114** is configured to urge the seal segments **108** towards the rotor **100**. In alternate embodiments, the spring **114** may also be configured as a coil spring that connects the seal segment(s) **108** with the stator **102**. In such embodiments, the spring **114** urges the seal segment(s) **108** away from the rotor **100**. Such an embodiment may be generally referred to herein as a retracted spring. Furthermore, in such embodiments, in the absence of differential seal pressure, the retracted spring pulls or “retracts” the seal segment(s) **108** away from the rotor **100**. Moreover, upon pressurization, the pressure forces overcome the spring force, and urge the seal segment(s) **108** towards the rotor **100**. In further embodiments, additional types of springs (e.g., tension springs, beam flexures, etc.) may be used to connect the seal segment(s) **108** to the stator **102** and/or the rotor **100**.

[0045] Referring particularly to FIGS. 4 and 5, various cross-sectional views of different embodiments of the portion of the turbomachine **16** of FIG. 2 along line 3-3 are illustrated. In particular, as shown in FIGS. 4 and 5, the stator **102** includes at least one feature **120** formed therein. As such, pressurized fluid engaging with the feature(s) **120** provides an aft-to-forward axial force F that reduces friction between interfacing aft surfaces **122** of the seal segments **108** and the stator **102**.

[0046] Referring particularly to FIG. 4, the feature(s) **120** is a recess **124** formed in a surface **126** of the stator **102** that creates an intermediate pressure region **128** between the high pressure region **110** and the low pressure region **112**. More specifically, as shown in the embodiment of FIG. 4, the stator **102** may generally have a U-shaped cross-sectional shape in the axial direction A of the gas turbine engine **10** that extends from a first side **130** of the seal assembly **106** in the low pressure region **112** to an opposing, second side **132** of the seal assembly **106** in the high pressure region **110**. Accordingly, in an embodiment, as shown in FIG. 4, the intermediate pressure region **128** is defined on the second side **132** of the seal segments **108**. Further, as shown, the intermediate pressure region **128** is forward of the seal assembly **106**. It should be understood that the stator **102** may be a unitary part or a segmented part. In such embodiments, where the stator **102** is formed of multiple parts, the U-shaped cross section may be formed of cover plate on the forward side, and an inverted L-shape on the aft side, such that when the forward cover plate and the inverted L-shape are attached together (e.g., bolted, welded, brazed, etc.), the resultant cross-sectional shape of the stator **102** is a U-shaped cross-section.

[0047] In such embodiments, pressurized fluid **127** in the intermediate pressure region **128** provides the aft-to-forward axial force F that minimizes the friction (e.g., the friction force acting in the radial direction perpendicular to the normal reaction acting in the axial direction) between the interfacing aft surfaces **122** of the seal assembly **106** and the stator **102**.

[0048] Still referring to FIG. 4, the seal assembly **106** may further include a low pressure vent **134** fluidly connecting the intermediate pressure region **128** to the low pressure region **112**. More specifically, as shown, the low pressure vent **134** is disposed in a through channel **136** that extends through at least a portion of the U-shaped cross-sectional shape of the stator **102**. Thus, as shown,

the pressurized fluid **127** in the intermediate pressure region **128** travels through the through channel **136** of the stator **102** and exits to the low pressure region **112** to provide the aft-to-forward axial force F that minimizes the friction between the interfacing aft surfaces **122** of the seal assembly **106** and the stator **102**. The reduced friction force (along the radial direction) is particularly beneficial because it does not hinder the ability of the seal segments **108** to dynamically track the radial excursions of the rotor **100**. Conversely, high frictional force can cause the seal segments **108** to become radially stuck on the aft support **122**, thereby causing the sealing face(s) **116** to rub against the rotor **100** in motion, thereby causing seal failure.

[0049] Referring now to FIG. **6**, another embodiment of a seal assembly **106** according to the present disclosure is illustrated. In particular, as shown, the rotor **100**, the stator **102**, and the plurality of seal segments **108** are arranged together to define a high pressure region **110** and a low pressure region **112**. The embodiment is similar in nature to the embodiment illustrated in FIGS. **2** and **3**. In addition, as shown in FIG. **6**, the seal segments **108** include a channel **135** that allows airflow from the intermediate pressure region **128** to the low pressure region **112**, e.g., through a body of the seal segments **108**.

[0050] In additional embodiments, as shown, the seal assembly **106** may also include a high pressure vent **142** fluidly connecting the exterior high pressure area **138** of the high pressure region **110** to the interior high pressure area **140** of the high pressure region **110**. More specifically, in an embodiment, as shown in FIG. **4**, the formation of the intermediate pressure region **128** on the forward side of the seal assembly **106** is enabled via the stator **102** being a U-shaped structure. The U-shaped structure also leads to the formation of the interior high pressure area **140**. As such, the pressure in the interior high pressure area **140** needs to be equal to $P_{sub.HIGH}$ such that sufficient closing force (along the radial direction) is generated to urge the seal segment(s) **108** towards the rotor **100**. Thus, the high pressure vent **142** allows the exterior high pressure area **138** to be connected to the interior high pressure area **140**, thereby ensuring sufficient seal closing force.

[0051] Referring now to FIG. **5**, as mentioned, a cross-sectional view of a different embodiment of the portion of the turbomachine **16** of FIG. **2** along line 3-3 is illustrated, particularly illustrating a different arrangement of the stator **102**. For example, as shown, the feature(s) **120** includes at least one fluid channel **144** formed therein. More specifically, as shown, the fluid channel(s) **144** fluidly connects high pressure fluid **146** (e.g., $P_{sub.HIGH}$) in the high pressure region **110** to the interfacing aft surfaces **122** of the seal segments **108** and the stator **102** to provide the aft-to-forward axial force F that minimizes the friction between the interfacing aft surfaces **122** of the seal segments **108** and the stator **102**. In addition, as shown, the fluid channel(s) **144** may include a primary fluid channel **148** and at least one fluid channel branch **150**, **152** extending from the primary fluid channel **148**.

[0052] Thus, in such embodiments, as shown, the fluid channel branch(es) **150**, **152** may include, at least, a first fluid channel branch **150** and a second fluid channel branch **152**. Further, as shown, the first and second fluid channel branches **150**, **152** may be arranged linearly in a radial direction. Accordingly, the fluid channel branch(es) **150**, **152** are configured to pressurize the interfacing aft surfaces **122** with the high pressure fluid **146** (e.g., $P_{sub.HIGH}$). As such, rather than a force equal to the high pressure fluid ($P_{sub.HIGH}$) plus half of the low pressure fluid ($P_{sub.LOW}$) acting on the interfacing aft surfaces **122**, more of the high pressure fluid **146** (e.g., $P_{sub.HIGH}$) is routed to the interfacing aft surfaces **122** to reduce the axial load (e.g., created by contact between the interfacing aft surfaces **122**). Furthermore, in certain embodiments, by providing multiple fluid channel branches arranged linearly in the radial direction R , the interfacing aft surfaces **122** will have $P_{sub.HIGH}$ no matter the radial location of the seal segments **108**. Moreover, as shown in FIG. **5**, the illustrated embodiment does not include the high pressure vent **142** (shown in FIG. **4**) because the embodiment does not include separate exterior and interior regions separated by the U-shaped structure of the stator **102** that requires such venting as described herein.

[0053] Referring now to FIG. **7**, a cross-sectional view of a still different embodiment of a portion

of the turbomachine **16** is illustrated, particularly illustrating a different arrangement of the stator **102**. In particular, as shown, the illustrated embodiment is similar to the embodiment of FIGS. **3** and **4**, except the illustrated seal is an aerostatic seal. Thus, as shown, the channel **113** and groove **118** are absent and the seal segment(s) **108** include an aerostatic port **154**. Accordingly, the illustrated seal assembly utilizes air from the high-pressure region **110** routed via the aerostatic port **154** to create an air film between the sealing face **116** and the opposing rotor **100**.

[0054] Further aspects are provided by the subject matter of the following clauses:

[0055] A turbine engine, comprising: a rotor; a stator; a circumferential seal assembly comprising a plurality of seal segments, the plurality of seal segments disposed between the rotor and the stator, wherein the rotor, the stator, and the plurality of seal segments are arranged together to define a high pressure region and a low pressure region; and a biasing member engaged with the seal assembly, wherein the stator comprises at least one feature formed therein, and wherein pressurized fluid engaging with the at least one feature provides an aft-to-forward axial force that reduces friction between interfacing aft surfaces of the plurality of seal segments and the stator.

[0056] The turbine engine of any preceding clause, wherein the at least one feature comprises a recess formed in a surface of the stator that creates an intermediate pressure region between the high pressure region and the low pressure region, and wherein the pressurized fluid in the intermediate pressure region provides the aft-to-forward axial force that minimizes the friction between the interfacing aft surfaces of the plurality of seal segments and the stator.

[0057] The turbine engine of any preceding clause, wherein the high pressure region is located forward of the low pressure region and the intermediate pressure region is forward of the seal assembly.

[0058] The turbine engine of any preceding clause, wherein the stator comprises a U-shaped cross-sectional shape in an axial direction of the turbine engine that extends from a first side of the seal assembly in the low pressure region to an opposing, second side of the seal assembly.

[0059] The turbine engine of any preceding clause, wherein the intermediate pressure region is defined on the second side of the seal assembly.

[0060] The turbine engine of any preceding clause, wherein the seal assembly further comprises a low pressure vent fluidly connecting the intermediate pressure region to the low pressure region.

[0061] The turbine engine of any preceding clause, wherein the low pressure vent extends through one or more of the plurality of seal segments.

[0062] The turbine engine of any preceding clause, wherein the low pressure vent is disposed in a through channel that extends through at least a portion of the U-shaped cross-sectional shape of the stator.

[0063] The turbine engine of any preceding clause, wherein the high pressure region comprises an exterior high pressure area external to the stator and an interior high pressure area interior of the stator.

[0064] The turbine engine of any preceding clause, wherein the seal assembly further comprises a high pressure vent fluidly connecting the exterior high pressure area to the interior high pressure area, wherein the high-pressure vent is fluidly separate from the low pressure vent.

[0065] The turbine engine of any preceding clause, wherein the at least one feature comprises at least one fluid channel formed in the stator, the at least one fluid channel configured for transporting high pressure fluid in the high pressure region to the interfacing aft surfaces of the plurality of seal segments and the stator to provide the aft-to-forward axial force that minimizes the friction between the interfacing aft surfaces of the plurality of seal segments and the stator.

[0066] The turbine engine of any preceding clause, wherein the at least one fluid channel comprises a primary fluid channel and at least one fluid channel branch extending from the primary fluid channel.

[0067] The turbine engine of any preceding clause, wherein the at least one fluid channel branch comprises, at least, a first fluid channel branch and a second fluid channel branch, the first and

second fluid channel branches arranged linearly in a radial direction.

[0068] The turbine engine of any preceding clause, further comprising at least one of a turbine or a compressor, wherein the rotor is at least one of a turbine rotor of the turbine or a compressor rotor of the compressor.

[0069] A seal assembly, comprising: a plurality of seal segments disposed between a rotor and a stator, wherein, when arranged together, the rotor, the stator, and the plurality of seal segments define a high pressure region and a low pressure region; a biasing member engaged with the plurality of seal segments; and at least one feature formed in the stator, wherein pressurized fluid engaging with the at least one feature provides an aft-to-forward axial force that reduces friction between interfacing aft surfaces of the plurality of seal segments and the stator.

[0070] The seal assembly of any preceding clause, wherein the at least one feature comprises a recess formed in a surface of the stator that creates an intermediate pressure region between the high pressure region and the low pressure region, and wherein the pressurized fluid in the intermediate pressure region provides the aft-to-forward axial force that minimizes the friction between the interfacing aft surfaces of the plurality of seal segments and the stator.

[0071] The seal assembly of any preceding clause, wherein the high pressure region is located forward of the low pressure region and the intermediate pressure region is forward of the seal assembly.

[0072] The seal assembly of any preceding clause, wherein the stator comprises a U-shaped cross-sectional shape that extends from a first side of the seal assembly in the low pressure region to an opposing, second side of the seal assembly, the intermediate pressure region being defined on the second side of the seal assembly.

[0073] The seal assembly of any preceding clause, wherein the seal assembly further comprises a low pressure vent fluidly connecting the intermediate pressure region to the low pressure region, and wherein the low pressure vent is disposed in at least one of a through channel that extends through at least a portion of the U-shaped cross-sectional shape of the stator or through one or more of the plurality of seal segments.

[0074] The seal assembly of any preceding clause, wherein the at least one feature comprises at least one fluid channel formed in the stator, the at least one fluid channel configured for transporting high pressure fluid in the high pressure region to the interfacing aft surfaces of the plurality of seal segments and the stator to provide the aft-to-forward axial force that minimizes the friction between the interfacing aft surfaces of the plurality of seal segments and the stator.

[0075] This written description uses examples to disclose the present 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.

Claims

1. A turbine engine comprising: a rotor; a stator; and a circumferential seal assembly comprising a plurality of seal segments, the plurality of seal segments disposed between the rotor and the stator, wherein the rotor, the stator, and the plurality of seal segments are arranged together to define a high pressure region and a low pressure region; wherein the stator comprises at least one feature formed therein, and wherein pressurized fluid engaging with the at least one feature provides an aft-to-forward axial force that reduces friction between interfacing aft surfaces of the plurality of seal segments and the stator, wherein the at least one feature comprises at least one fluid channel

formed in the stator, the at least one fluid channel configured for transporting high pressure fluid in the high pressure region to the interfacing aft surfaces of the plurality of seal segments and the stator to provide the aft-to-forward axial force that minimizes the friction between the interfacing aft surfaces of the plurality of seal segments and the stator.

2. The turbine engine of claim 1, wherein the at least one fluid channel comprises a primary fluid channel and at least one fluid channel branch extending from the primary fluid channel.

3. The turbine engine of claim 2, wherein the at least one fluid channel branch comprises a first fluid channel branch and a second fluid channel branch, the first and second fluid channel branches arranged linearly in a radial direction.

4. The turbine engine of claim 3, wherein the first fluid channel branch and the second fluid channel branch are configured to pressurize the interacting aft surfaces of the plurality of seal segments and the stator.

5. The turbine engine of claim 1, further comprising at least one of a turbine or a compressor, wherein the rotor is at least one of a turbine rotor of the turbine or a compressor rotor of the compressor.

6. The turbine engine of claim 1, further comprising a biasing member engaged with the seal assembly.

7. The turbine engine of claim 6, wherein the biasing member is a compression spring urging contact between the plurality of seal segments and the rotor.

8. The turbine engine of claim 6, wherein the biasing member is a coil spring connecting the plurality of seal segments to the stator.

9. The turbine engine of claim 1, wherein at least one of the plurality of seal segments defines a channel and a groove, the channel connecting the high pressure region to the groove.

10. The turbine engine of claim 9, wherein the groove is outward in a radial direction from the rotor.

11. The turbine engine of claim 1, wherein at least one of the plurality of seal segments includes a tooth engaging the stator to form a seal between the high pressure region and the low pressure region.

12. The turbine engine of claim 11, wherein the at least one fluid channel comprises a primary fluid channel, a first fluid channel branch extending from the primary fluid channel, and a second fluid channel branch extending from the primary fluid channel, the first and second fluid channel branches arranged linearly in a radial direction, wherein the first fluid channel branch is disposed adjacent to the tooth in the an axial direction, an wherein the second fluid channel branch is disposed outward of the tooth in the radial direction.

13. The turbine engine of claim 11, wherein the tooth includes the respective interacting aft surface of the at least one of the plurality of seal segments.

14. A seal assembly comprising: a plurality of seal segments disposed between a rotor and a stator, wherein, when arranged together, the rotor, the stator, and the plurality of seal segments define a high pressure region and a low pressure region; and at least one feature formed in the stator, wherein pressurized fluid engaging with the at least one feature provides an aft-to-forward axial force that reduces friction between interfacing aft surfaces of the plurality of seal segments and the stator, wherein the at least one feature comprises at least one fluid channel formed in the stator, the at least one fluid channel configured for transporting high pressure fluid in the high pressure region to the interfacing aft surfaces of the plurality of seal segments and the stator to provide the aft-to-forward axial force that minimizes the friction between the interfacing aft surfaces of the plurality of seal segments and the stator.

15. The seal assembly of claim 14, wherein the at least one fluid channel comprises a primary fluid channel and at least one fluid channel branch extending from the primary fluid channel.

16. The seal assembly of claim 15, wherein the at least one fluid channel branch comprises a first fluid channel branch and a second fluid channel branch, the first and second fluid channel branches

arranged linearly in a radial direction.

17. The seal assembly of claim 14, further comprising a biasing member engaged with the plurality of seal segments.

18. The seal assembly of claim 17, wherein the biasing member is a compression spring.

19. The seal assembly of claim 14, wherein at least one of the plurality of seal segments defines a channel and a groove.

20. The seal assembly of claim 14, wherein at least one of the plurality of seal segments includes a tooth configured to engage the stator to form a seal between the high pressure region and the low pressure region.
