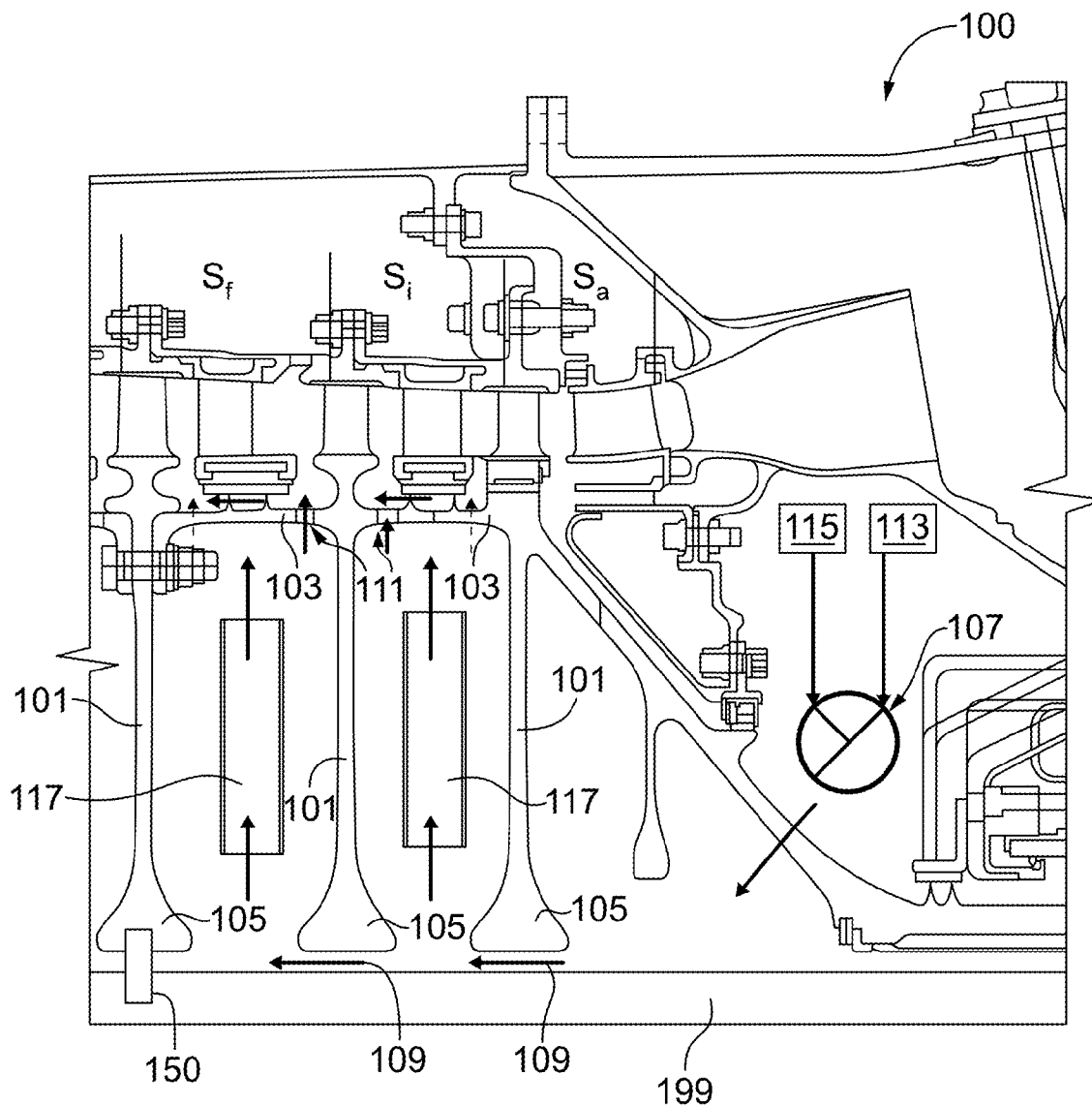




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(19) **United States**(12) **Patent Application Publication**
Forcier et al.(10) **Pub. No.: US 2016/0076379 A1**(43) **Pub. Date: Mar. 17, 2016**(54) **TURBOMACHINE ROTOR THERMAL
REGULATION SYSTEMS****Publication Classification**(71) Applicant: **United Technologies Corporation,**
Farmington, CT (US)(51) **Int. Cl.**
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(US)(52) **U.S. Cl.**
CPC **F01D 5/081** (2013.01)(21) Appl. No.: **14/851,912**(22) Filed: **Sep. 11, 2015****Related U.S. Application Data**(60) Provisional application No. 62/050,033, filed on Sep.
12, 2014.(57) **ABSTRACT**

A turbomachine includes an aft stage including a rotor disk having a rotor disk bore hole and a rotor disk rim, and a valve disposed within the turbomachine and in fluid communication with the rotor disk bore hole. The valve is in selective fluid communication with a first pressure source such that, in an first position, the valve allows fluid to flow from the first pressure source through the rotor disk bore hole and radially outward along the aft rotor disk toward the aft rotor disk rim.



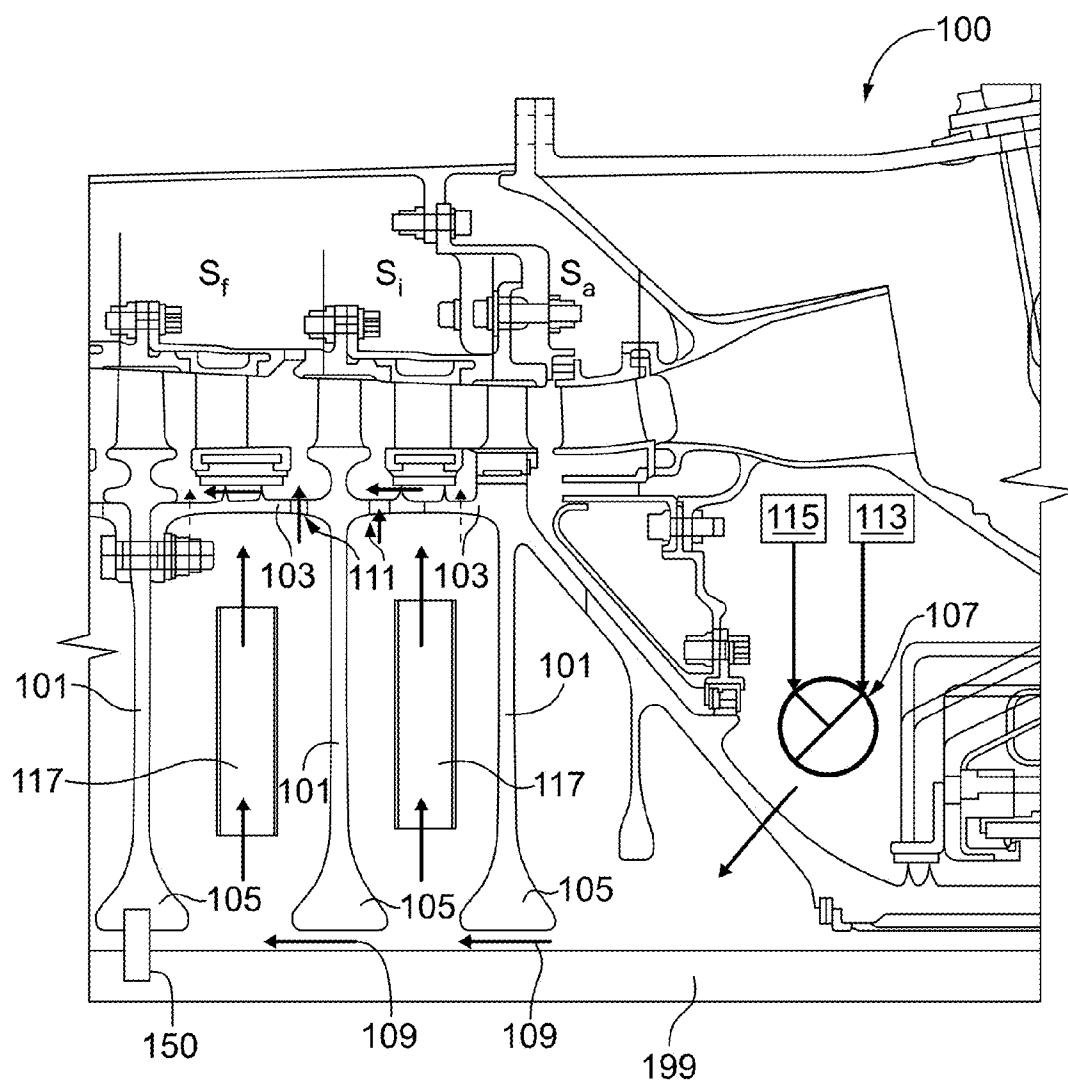


FIG. 1

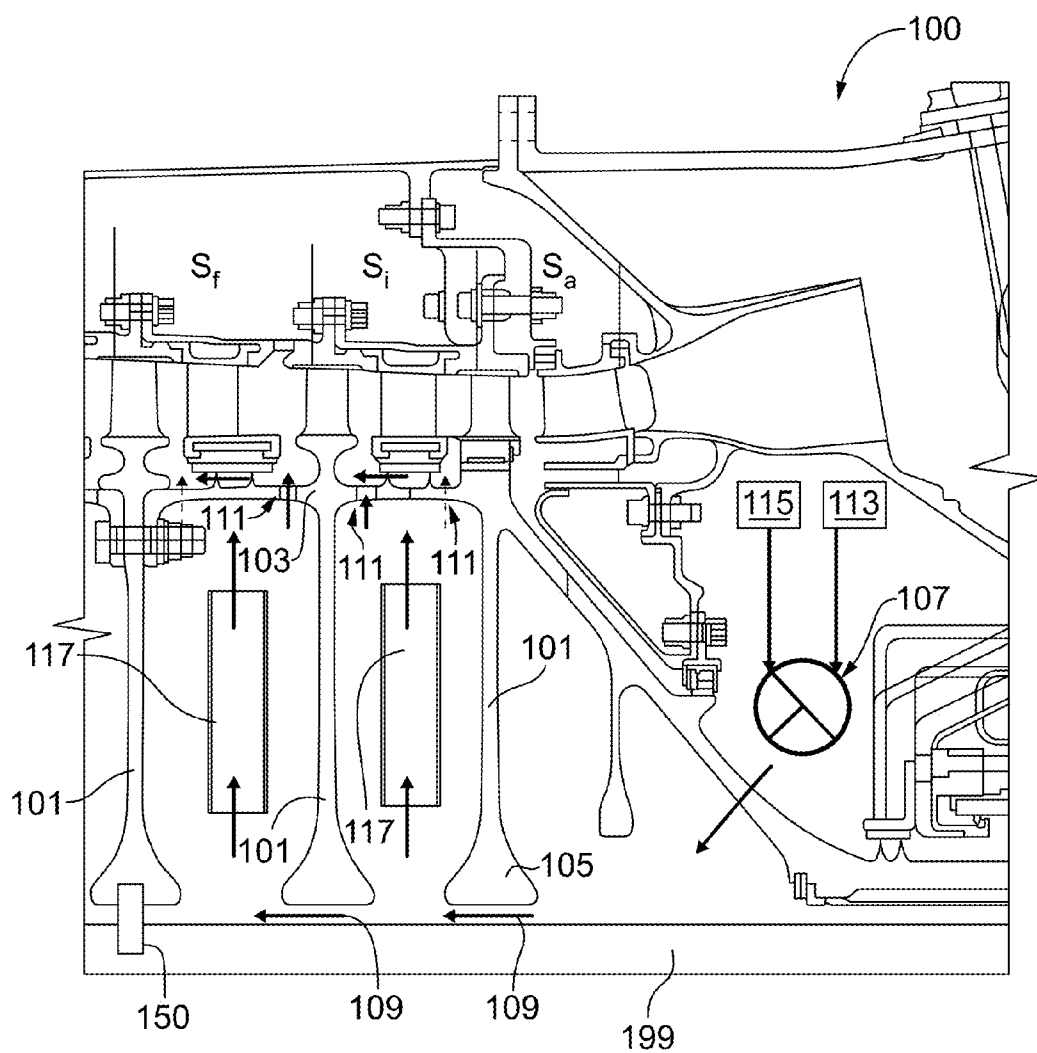


FIG. 2

TURBOMACHINE ROTOR THERMAL REGULATION SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 62/050,033, filed Sep. 12, 2014, the entire contents of which are incorporated herein by reference thereto.

BACKGROUND

[0002] The present disclosure relates to turbomachine components and systems, more specifically components and systems configured for thermal regulation thereof.

[0003] Turbomachine compressors include a series of blades connected to rotor disks which are operatively disposed on or about a shaft to rotate (e.g., high pressure compressors can be disposed rotatable relative to a shaft via bearings or the like). Each blade has a corresponding stator, which together with the blade, form a stage. The disks can include pathways at the bore portion which to allow cooling airflow to pass through close to the shaft.

[0004] Traditionally, a forward stage can include a bleed to allow cool air to flow from the rim of the rotor disk through rotor cavity, down toward the shaft through the bore holes, and out to a pressure sink (e.g., turbine). However, this type of cooling does not regulate temperature differentials in more aft stages of the compressor. At certain operational regimes, the rotor disks in aft stages can experience dramatic temperature differentials between the disk rim and the disk bore which stresses the disk material decreasing disk life. For example, in low power operation of a compressor, the shaft and/or bore can experience high heat whereas the rim experiences lower heat, causing material stress on the rotor disks. At higher power settings, the gas in the more aft stages becomes hotter due to high compression, and the rim of each rotor disk can be much hotter than the bore thereof, causing material stress.

[0005] Such conventional methods and systems have generally been considered satisfactory for their intended purpose. However, there is still a need in the art for improved thermal regulation in turbomachines. The present disclosure provides a solution for this need.

SUMMARY

[0006] In at least one aspect of this disclosure a turbomachine includes an aft stage including a rotor disk having a rotor disk bore hole and a rotor disk rim, and a valve disposed within the turbomachine and in fluid communication with the rotor disk bore hole. The valve is in selective fluid communication with a first pressure source such that, in a first position, the valve allows fluid to flow from the first pressure source through the rotor disk bore hole and radially outward along the aft rotor disk toward the aft rotor disk rim.

[0007] The first pressure source can be a cold air source. The first pressure source can be a hot air source. The turbomachine can further include a second pressure source including a fluid of a different temperature than the first pressure source. In some embodiments, the first pressure source can be a cold air source and the second pressure source can be a hot air source.

[0008] The valve can be operatively connected to a control system for determining when to allow flow from the first pressure source. The valve can be configured to modify flow

rate from the first pressure source. The valve can be configured to shut off flow from the first pressure source. In some embodiments, the valve can be operatively connected to a control system for determining when to allow flow from the first pressure source and/or the second pressure source based on an operational characteristic of the turbomachine.

[0009] The aft stage can include an anti-vortex tube disposed in a cavity between the aft rotor disk and a second rotor disk that is forward of the aft rotor disk to facilitate radially outward flow therein.

[0010] The turbomachine can further include at least one intermediate stage rotor disk that can include an intermediate stage rotor disk bore hole in fluid communication with the valve. Each intermediate stage rotor disk can include an anti-vortex tube disposed thereon to facilitate radially outward flow therealong. In such embodiments, each anti-vortex tube can be sized to balance flow rates of cooling flow between each stage. The turbomachine can further include a forward stage rotor disk that is sealed at a forward stage rotor disk bore to prevent flow from any rotor disk aft thereof from flowing therethrough.

[0011] In at least one aspect of this disclosure, a method includes determining an operational characteristic of a turbomachine, and providing an airflow to a rotor disk of a turbomachine compressor for thermal regulation of the rotor disk based on the operational characteristic. Providing an airflow can include modifying a state of a valve to allow at least one of a cold air or a hot air to flow to the rotor disk or to modify the total flow rate of the cold air and/or the hot air based on the operational characteristic.

[0012] Determining the operational characteristic can include determining the temperature of one or more components of the turbomachine. In some embodiments, determining the operational characteristic can include determining the speed of one or more components of the turbomachine. Determining the operational characteristic can include determining the power setting and/or output of the turbomachine.

[0013] In one embodiment, a turbomachine is provided. The turbomachine having: an aft stage including a rotor disk having a rotor disk bore hole and a rotor disk rim; and a valve disposed within the turbomachine and in fluid communication with the rotor disk bore hole, wherein the valve is in selective fluid communication with a first pressure source, such that in a first position, the valve allows fluid to flow from the first pressure source through the rotor disk bore hole and radially outward along the aft rotor disk toward the aft rotor disk rim.

[0014] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the first pressure source of the turbomachine may be a cold air source.

[0015] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the first pressure source of the turbomachine may be a hot air source.

[0016] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the turbomachine may further include a second pressure source including a fluid of a different temperature than the first pressure source.

[0017] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodi-

ments, the first pressure source of the turbo machine may be a cold air source and the second pressure source is a hot air source.

[0018] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the aft stage of the turbomachine may include an anti-vortex tube disposed in a cavity between the aft rotor disk and a second rotor disk that is forward of the aft rotor disk to facilitate radially outward flow therein.

[0019] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the at least one intermediate stage rotor disk of the turbomachine may include an intermediate stage rotor disk bore hole in fluid communication with the valve.

[0020] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, each intermediate stage of the turbo machine may include an anti-vortex tube disposed thereon to facilitate radially outward flow therealong.

[0021] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, each anti-vortex tube of the turbomachine may be sized to balance a pressure drop between each stage.

[0022] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the turbomachine may include a forward stage rotor disk that is sealed at a forward stage rotor disk bore to prevent flow from any rotor disk aft thereof from flowing there-through.

[0023] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the valve of the turbomachine may be operatively connected to a control system for determining when to allow flow from the first pressure source.

[0024] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the valve of the turbomachine may be configured to modify flow rate from the first pressure source.

[0025] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the valve of the turbomachine may be configured to shut off flow from the first pressure source.

[0026] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the valve of the turbomachine may be operatively connected to a control system for determining when to allow flow from the first pressure source and/or the second pressure source based on an operational characteristic of the turbomachine.

[0027] In another embodiment of the disclosure, a method is provided. The method including the steps of: determining an operational characteristic of a turbomachine; and providing high pressure air to a rotor disk of a turbomachine compressor for thermal regulation of the rotor disk based on the operational characteristic.

[0028] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, wherein the step of providing an airflow may include modifying a state of a valve to allow at least one of a cold air or a hot air to flow to the rotor disk or to modify the total flow rate of the cold air and/or the hot air based on the operational characteristic.

[0029] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments,

the step of determining the operational characteristic may include determining the temperature of one or more components of the turbomachine.

[0030] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the step of determining the operational characteristic may include determining the speed of one or more components of the turbomachine.

[0031] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the step of determining the operational characteristic may include determining the power setting and/or output of the turbomachine.

[0032] These and other features of the systems and methods of the subject disclosure will become more readily apparent to those skilled in the art from the following detailed description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] So that those skilled in the art to which the subject disclosure appertains will readily understand how to make and use the devices and methods of the subject disclosure without undue experimentation, embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

[0034] FIG. 1 is a partial cross-sectional view of an embodiment of a portion of a turbomachine in accordance with this disclosure, shown including a plurality of rotor disks in accordance with this disclosure and a valve in a hot air configuration; and

[0035] FIG. 2 is a partial cross-sectional view of the embodiment of FIG. 1, showing the valve in a cold air configuration.

DETAILED DESCRIPTION

[0036] Reference will now be made to the drawings wherein like reference numerals identify similar structural features or aspects of the subject disclosure. For purposes of explanation and illustration, and not limitation, an illustrative view of an embodiment of a portion of a turbomachine is shown in accordance with the disclosure is shown in FIGS. 1 and 2, and is designated generally by reference character 100. The systems and methods described herein can be used to enhance thermal regulation of portions of a turbomachine (e.g., to reduce rotor disk temperature differential between the rim and the bore).

[0037] In at least one aspect of this disclosure a turbomachine 100 includes an aft stage S_a , including rotor disk 101 disposed around a shaft 199, a bore basket, or any other suitable device. The rotor disk 101 is not necessarily connected to the shaft 199, but can be rotatable relative to shaft 199 on bearings or any other suitable arrangement. The rotor disk 101 includes a rotor disk bore hole 109 define in a rotor disk bore portion 105 of the rotor disk 101. The rotor disk 101 can also include a rotor disk rim 103.

[0038] A valve 107 is disposed within the turbomachine 100 and is in fluid communication with the rotor disk bore hole 109. Any suitable valve 107 is contemplated for use as disclosed herein. The valve 107 is in selective fluid communication with at least a first pressure source (e.g., cold air source 113) such that, in a first position, the valve 107 allows fluid to flow from the first pressure source through the rotor disk bore hole 109 and radially outward along the rotor disk

101 toward the rotor disk rim **103**. The valve **107** can also operate to mix various amounts of hot air (e.g., from hot air source **115**) and cold air (e.g., from cold air source **113**) and/or to control the total amount of flow supplied to the rotor disks **101** from one or more of the air source **113**, **115** for achieving desired thermal regulation of rotor disks **101**.

[0039] The valve **107** can be operatively connected to a suitable control system (not shown) for determining when to allow flow from one or more of the air sources **113**, **115**. The valve **107** can be configured to modify flow rate from one or more of the air sources **113**, **115**. In embodiments, the valve **107** can be configured to shut off flow from one or more of the air sources **113**, **115** or always allow flow from at least one source or a mixture thereof.

[0040] In some embodiments, the valve **107** can be operatively connected to a control system for determining when to allow flow from the cold air source **113** and/or the hot air source **115** based on any suitable operational characteristic of the turbomachine (e.g., temperature of one or more components, operational speed, and/or operational power).

[0041] As shown in FIG. 1, the first pressure source can be a cold air source **113**. It is also contemplated that the first pressure source can be a hot air source **115**. As shown in the embodiment of FIGS. 1 and 2, the turbomachine **100** can also include a second pressure source including a fluid of a different temperature than the first pressure source. For example, the first pressure source can be a cold air source **113** and the second pressure source can be a hot air source **115**.

[0042] In embodiments as shown, the aft stage can include an anti-vortex tube **117** disposed in a cavity between rotor disks **101** to facilitate radially outward flow therein. The anti-vortex tube **117** can provide a pressure increase and can be sized to provide required flow rates to the cavity to suitably regulate the rotor disk **101** temperature differential.

[0043] The turbomachine **100** can further include at least one intermediate stage S_i which includes a rotor disk **101** having a bore hole **109** also in fluid communication with the valve **107**. In such a case, one or more intermediate stage rotor disks **101** can also include an anti-vortex tube **117** disposed thereon to facilitate radially outward flow therealong. In such embodiments, each anti-vortex tube **117** can be sized to balance the cooling flow in and between each stage. Some cavities may require more flow than others to provide the required thermal conditioning.

[0044] The turbomachine can further include a forward stage S_f having a rotor disk **101** that is sealed at the bore portion **105** using any suitable means (e.g., seal **150**, using a disk **101** without a bore hole **109**) so as to prevent flow from any rotor disk **101** that is aft thereof from flowing forward therethrough.

[0045] One or more bleeds **111** can be included in the rim **103** of one or more of the rotor disks **101** so as to allow flow to travel radially outward and through the rims **103** as shown in FIGS. 1 and 2. One or more of the bleeds **111** can be located either upstream or downstream of a sealing feature (e.g., a labyrinth seal) that is disposed in the rim portion **103** of any of the disks **101**. In some cases, bleeds **111** located upstream of the sealing feature allow seal temperatures to be regulated at the expense of extra pressure. Bleeds **111** located downstream of the sealing feature can require less pressure.

[0046] Creating such selective flow paths regulates a temperature differential of the rotor disks **101** such that the temperature differential between the rim **103** and the bore **105** of the rotor disks **101** is reduced during some operational

regimes. For example, at idle, valve **107** can allow hot air from the hot air source to travel to the disks **101** (e.g., as shown in FIG. 1). During power up, any suitable mixture of hot air from the hot air source **115** and/or cold air from the cold air source **113** can be provided. At a full power setting, the valve **107** can allow cold air to flow to the disks **101** for maximum cooling (e.g., as shown in FIG. 2). During a cruise setting, the valve **107** can allow cold air, but of a suitable modified flow rate, to travel to the rotor disks **101** for optimized cooling to reduce thermal gradient between the rims **103** and bore **105**.

[0047] While the embodiment depicted in FIGS. 1 and 2 is shown in an exemplary engine, any other suitable arrangement of forward, intermediate, aft stages, and pluralities thereof to create a desired flow path therebetween are contemplated herein.

[0048] In at least one aspect of this disclosure, a method includes determining an operational characteristic of a turbomachine **100**, and providing an airflow to a rotor disk of a turbomachine compressor for thermal regulation of a rotor disk **101** based on the operational characteristic. Providing an airflow can include modifying a state of a valve **107** to allow at least one of a cold air or a hot air to flow to the rotor disk **101** based on the operational characteristic.

[0049] Determining the operational characteristic can include determining the temperature of one or more components of the turbomachine **100**. In some embodiments, determining the operational characteristic can include determining the speed of one or more components of the turbomachine **100**. Determining the operational characteristic can include determining the power setting and/or output of the turbomachine **100**.

[0050] The methods and systems of the present disclosure, as described above and shown in the drawings, provide for a turbomachine and/or rotor disk with superior properties including enhanced thermal regulation and overall lower temperature. While the apparatus and methods of the subject disclosure have been shown and described with reference to embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the spirit and scope of the subject disclosure.

What is claimed is:

1. A turbomachine, comprising:

an aft stage including a rotor disk having a rotor disk bore hole and a rotor disk rim; and

a valve disposed within the turbomachine and in fluid communication with the rotor disk bore hole, wherein the valve is in selective fluid communication with a first pressure source, such that in an first position, the valve allows fluid to flow from the first pressure source through the rotor disk bore hole and radially outward along the aft rotor disk toward the aft rotor disk rim.

2. The turbomachine of claim 1, wherein the first pressure source is a cold air source.

3. The turbomachine of claim 1, wherein the first pressure source is a hot air source.

4. The turbomachine of claim 1, further including a second pressure source including a fluid of a different temperature than the first pressure source.

5. The turbomachine of claim 4, wherein the first pressure source is a cold air source and the second pressure source is a hot air source.

6. The turbomachine of claim 1, wherein the aft stage includes an anti-vortex tube disposed in a cavity between the aft rotor disk and a second rotor disk that is forward of the aft rotor disk to facilitate radially outward flow therein.

7. The turbomachine of claim 1, including at least one intermediate stage rotor disk including an intermediate stage rotor disk bore hole in fluid communication with the valve.

8. The turbomachine of claim 7, wherein each intermediate stage includes an anti-vortex tube disposed thereon to facilitate radially outward flow therealong.

9. The turbomachine of claim 8, wherein each anti-vortex tube is sized to balance a pressure drop between each stage.

10. The turbomachine of claim 1, further including a forward stage rotor disk that is sealed at a forward stage rotor disk bore to prevent flow from any rotor disk aft thereof from flowing therethrough.

11. The turbomachine of claim 1, wherein the valve is operatively connected to a control system for determining when to allow flow from the first pressure source.

12. The turbomachine of claim 1, wherein the valve is configured to modify flow rate from the first pressure source.

13. The turbomachine of claim 1, wherein the valve is configured to shut off flow from the first pressure source.

14. The turbomachine of claim 5, wherein the valve is operatively connected to a control system for determining

when to allow flow from the first pressure source and/or the second pressure source based on an operational characteristic of the turbomachine.

15. A method, comprising:

determining an operational characteristic of a turbomachine; and

providing high pressure air to a rotor disk of a turbomachine compressor for thermal regulation of the rotor disk based on the operational characteristic.

16. The method of claim 15, wherein providing an airflow includes modifying a state of a valve to allow at least one of a cold air or a hot air to flow to the rotor disk or to modify the total flow rate of the cold air and/or the hot air based on the operational characteristic.

17. The method of claim 15, wherein determining the operational characteristic includes determining the temperature of one or more components of the turbomachine.

18. The method of claim 15, wherein determining the operational characteristic includes determining the speed of one or more components of the turbomachine.

19. The method of claim 15, wherein determining the operational characteristic includes determining the power setting and/or output of the turbomachine.

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