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United States Patent	12392289
Kind Code	B2
Date of Patent	August 19, 2025
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Active bleed flow modulation

Abstract

A bleed air cooling system for a gas turbine engine includes a bleed port located at an axial location of the gas turbine engine to divert a bleed airflow from a gas turbine engine flowpath, a bleed outlet located at a cooling location of the gas turbine engine and a bleed duct in fluid communication with the bleed port and the configured to convey the bleed airflow from the bleed port to the bleed outlet. A modulating valve is located at the bleed duct and is movable between a fully open position and a fully closed position to regulate the bleed airflow through the bleed duct based on one or more operating conditions of the gas turbine engine.

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Appl. No.: **15/601499**

Filed: **May 22, 2017**

Prior Publication Data

Document Identifier	Publication Date
US 20180334962 A1	Nov. 22, 2018

Publication Classification

Int. Cl.: **F02C7/18** (20060101); **F02C6/08** (20060101); **F02C9/18** (20060101); F02C7/057 (20060101); F16K31/00 (20060101)

U.S. Cl.:

CPC **F02C7/18** (20130101); **F02C6/08** (20130101); **F02C9/18** (20130101); F01P2023/00 (20130101); F01P2025/04 (20130101); F01P2025/08 (20130101); F02C7/057 (20130101); F05D2270/301 (20130101); F05D2270/303 (20130101); F16K31/00 (20130101)

Field of Classification Search

USPC: None

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Background/Summary

BACKGROUND
(1) Exemplary embodiments pertain to the art of gas turbine engines. More particularly, the present disclosure relates to cooling of components of the gas turbine engine via bleed air flow.
(2) Gas turbine engines are known and typically include a fan delivering air into a bypass duct as propulsion air. Further, the fan delivers air into a compressor section where it is compressed. The compressed air passes into a combustion section where it is mixed with fuel and ignited. Products of this combustion pass downstream over turbine rotors driving them to rotate.
(3) In a gas turbine engine, cooling air is often provided from the compressor to the turbine section to reduce component temperature in the turbine section and improve overall gas turbine engine operation. In some gas turbine engines, air from the high compressor discharge is passed through a heat exchanger, which may be located in a fan bypass duct and then delivered into the turbine section as cooling air. The air from the downstream most end of the compressor section is at elevated temperatures, relative to air at other portions of the compressor section.
(4) Running the operating temperatures in the turbine section at high temperatures provides efficiency gains in the gas turbine engine; however, the high temperatures are exceeding material limits and are driving the need for improved cooling air. That is, conventional cooling air methods often require large amounts of airflow to provide cooling air at sufficient pressure to be introduced to the highest pressure places of the gas turbine engine and at cool enough temperature to reduce key component temperatures.
BRIEF DESCRIPTION
(5) In one embodiment, a bleed air cooling system for a gas turbine engine includes a bleed port located at an axial location of the gas turbine engine to divert a bleed airflow from a gas turbine engine flowpath, a bleed outlet located at a cooling location of the gas turbine engine and a bleed duct in fluid communication with the bleed port and the configured to convey the bleed airflow from the bleed port to the bleed outlet. A modulating valve is located at the bleed duct and is movable between a fully open position and a fully closed position to regulate the bleed airflow through the bleed duct based on one or more operating conditions of the gas turbine engine.
(6) Additionally or alternatively, in this or other embodiments the one or more operating conditions are one or more properties of the bleed airflow entering the bleed port.
(7) Additionally or alternatively, in this or other embodiments one or more sensors are located at the bleed duct to sense the one or more operating conditions, the modulating valve responsive to the one or more operating conditions sensed by the one or more sensors.
(8) Additionally or alternatively, in this or other embodiments the one or more sensors include a pressure sensor or a temperature sensor.
(9) Additionally or alternatively, in this or other embodiments a control system is operably

connected to the modulating valve and is configured to command the modulating valve to a selected position based on the one or more operating conditions.
(10) Additionally or alternatively, in this or other embodiments the bleed airflow is diverted from a high pressure compressor of the gas turbine engine.
(11) Additionally or alternatively, in this or other embodiments the bleed outlet is located at a turbine section of the gas turbine engine.
(12) In another embodiment, a gas turbine engine includes a compressor section, a turbine section operably connected to the compressor section, and a bleed air cooling system. The bleed air cooling system includes a bleed port located at the compressor section to divert a bleed airflow from a gas turbine engine flowpath, a bleed outlet located at a cooling location of the gas turbine engine, and a bleed duct in fluid communication with the bleed port and the configured to convey the bleed airflow from the bleed port to the bleed outlet. A modulating valve is located at the bleed duct, and is movable between a fully open position and a fully closed position to regulate the bleed airflow through the bleed duct based on one or more operating conditions of the gas turbine engine.
(13) Additionally or alternatively, in this or other embodiments the one or more operating conditions are one or more properties of the bleed airflow entering the bleed port.
(14) Additionally or alternatively, in this or other embodiments one or more sensors are located at the bleed duct to sense the one or more operating conditions, the modulating valve responsive to the one or more operating conditions sensed by the one or more sensors.
(15) Additionally or alternatively, in this or other embodiments the one or more sensors include a pressure sensor or a temperature sensor.
(16) Additionally or alternatively, in this or other embodiments a control system is operably connected to the modulating valve and is configured to command the modulating valve to a selected position based on the one or more operating conditions.
(17) Additionally or alternatively, in this or other embodiments the bleed airflow is diverted from a high pressure compressor of the gas turbine engine.
(18) Additionally or alternatively, in this or other embodiments the bleed outlet is located at the turbine section of the gas turbine engine.
(19) In yet another embodiment, a method of cooling one or more components of a gas turbine engine includes urging a bleed airflow through a bleed port located at a first axial location of a compressor section of a gas turbine engine, flowing the bleed airflow through a bleed duct toward a bleed outlet located at a cooling location, sensing one or more operating conditions of the gas turbine engine, and operating a modulating valve located in the bleed duct based on the sensed operating conditions to regulate the bleed airflow through the bleed duct.
(20) Additionally or alternatively, in this or other embodiments sensing the one or more operating conditions includes sensing one or more of a pressure or a temperature of the bleed airflow entering the bleed duct.
(21) Additionally or alternatively, in this or other embodiments the modulating valve is movable between a fully open position and a fully closed position.
(22) Additionally or alternatively, in this or other embodiments operating of the modulating valve is commanded via a command from a control system operably connected to the modulating valve.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:
(2) FIG. **1** is cross-sectional view of an embodiment of a gas turbine engine;
(3) FIG. **2** is a schematic view of an embodiment of a bleed system for a gas turbine engine; and

(4) FIG. **3** is a schematic of another embodiment of a bleed system for a gas turbine engine.
DETAILED DESCRIPTION
(5) A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.
(6) FIG. **1** schematically illustrates a gas turbine engine **20**. The gas turbine engine **20** is disclosed herein as a two-spool turbofan that generally incorporates a fan section **22**, a compressor section **24**, a combustor section **26** and a turbine section **28**. Alternative engines might include an augmentor section (not shown) among other systems or features. The fan section **22** drives air along a bypass flow path B in a bypass duct, while the compressor section **24** drives air along a core flow path C for compression and communication into the combustor section **26** then expansion through the turbine section **28**. Although depicted as a two-spool turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with two-spool turbofans as the teachings may be applied to other types of turbine engines including three-spool architectures.
(7) The exemplary engine **20** generally includes a low speed spool **30** and a high speed spool **32** mounted for rotation about an engine central longitudinal axis A relative to an engine static structure **36** via several bearing systems **38**. It should be understood that various bearing systems **38** at various locations may alternatively or additionally be provided, and the location of bearing systems **38** may be varied as appropriate to the application.
(8) The low speed spool **30** generally includes an inner shaft **40** that interconnects a fan **42**, a low pressure compressor **44** and a low pressure turbine **46**. The inner shaft **40** is connected to the fan **42** through a speed change mechanism, which in exemplary gas turbine engine **20** is illustrated as a geared architecture **48** to drive the fan **42** at a lower speed than the low speed spool **30**. The high speed spool **32** includes an outer shaft **50** that interconnects a high pressure compressor **52** and high pressure turbine **54**. A combustor **56** is arranged in exemplary gas turbine **20** between the high pressure compressor **52** and the high pressure turbine **54**. An engine static structure **36** is arranged generally between the high pressure turbine **54** and the low pressure turbine **46**. The engine static structure **36** further supports bearing systems **38** in the turbine section **28**. The inner shaft **40** and the outer shaft **50** are concentric and rotate via bearing systems **38** about the engine central longitudinal axis A which is collinear with their longitudinal axes.
(9) The core airflow is compressed by the low pressure compressor **44** then the high pressure compressor **52**, mixed and burned with fuel in the combustor **56**, then expanded over the high pressure turbine **54** and low pressure turbine **46**. The turbines **46**, **54** rotationally drive the respective low speed spool **30** and high speed spool **32** in response to the expansion. It will be appreciated that each of the positions of the fan section **22**, compressor section **24**, combustor section **26**, turbine section **28**, and fan drive gear system **48** may be varied. For example, gear system **48** may be located aft of combustor section **26** or even aft of turbine section **28**, and fan section **22** may be positioned forward or aft of the location of gear system **48**.
(10) The engine **20** in one example is a high-bypass geared aircraft engine. In a further example, the engine **20** bypass ratio is greater than about six (6), with an example embodiment being greater than about ten (10), the geared architecture **48** is an epicyclic gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3 and the low pressure turbine **46** has a pressure ratio that is greater than about five. In one disclosed embodiment, the engine **20** bypass ratio is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor **44**, and the low pressure turbine **46** has a pressure ratio that is greater than about five 5:1. Low pressure turbine **46** pressure ratio is pressure measured prior to inlet of low pressure turbine **46** as related to the pressure at the outlet of the low pressure turbine **46** prior to an exhaust nozzle. The geared architecture **48** may be an epicycle gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3:1. It should be understood, however, that the above parameters are only

exemplary of one embodiment of a geared architecture engine and that the present disclosure is applicable to other gas turbine engines including direct drive turbofans.

(11) A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The fan section **22** of the engine **20** is designed for a particular flight condition—typically cruise at about 0.8 Mach and about 35,000 feet (10,688 meters). The flight condition of 0.8 Mach and 35,000 ft (10,688 meters), with the engine at its best fuel consumption—also known as “bucket cruise Thrust Specific Fuel Consumption (‘TSFC’)”—is the industry standard parameter of lbm of fuel being burned divided by lbf of thrust the engine produces at that minimum point. “Low fan pressure ratio” is the pressure ratio across the fan blade alone, without a Fan Exit Guide Vane (“FEGV”) system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.45. “Low corrected fan tip speed” is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of [(Tram ° R)/(518.7° R)].sup.0.5. The “Low corrected fan tip speed” as disclosed herein according to one non-limiting embodiment is less than about 1150 ft/second (350.5 m/sec).

(12) Referring now to FIG. **2**, illustrated is an embodiment of a bleed air cooling system **72** for the gas turbine engine **10**. In this embodiment, the compressor section **24** includes a bleed port **58** connected to a bleed duct **60** via bleed manifold **62**. In some embodiments, the bleed port **58** is located at the high pressure compressor **52** to divert high pressure compressor airflow **64** from the high pressure compressor **52** into the bleed duct **60** as bleed airflow **66**. The bleed airflow **66** is directed downstream along the bleed duct **60** to one or more locations of, for example, the turbine section **28** to provide cooling for one or more components thereat. In the embodiment of FIG. **2**, a turbine manifold **68** is connected to the bleed duct **60**, and extends at least partially around a perimeter of the turbine section **28** to allow for distribution of the bleed airflow **66** to multiple circumferential locations of the turbine section **28**. In some embodiments, the turbine manifold **68** extends completely around the perimeter of the turbine section **28**. The bleed airflow **66** flows from the turbine manifold **68** to cool one or more components of the turbine section **28**, for example, one or more turbine airfoils **70**.

(13) Under some operating conditions of the bleed air cooling system **72** and/or of the gas turbine engine **10**, it is desired to provide an increased or decreased flow of bleed airflow **66** to the turbine manifold **68**, to modulate the bleed airflow **66**. To accomplish this modulation of the bleed airflow **66**, a modulating valve **74** is located in the bleed air cooling system **72**, for example, along the bleed duct **60** between the bleed manifold **62** and the turbine manifold **68**. The modulating valve **74** can be positioned anywhere between a fully opened position and a fully closed position such that a flow rate of the bleed airflow **66** through the bleed duct **60** is customizable based on selected operating conditions.

(14) The bleed air cooling system **72** of the present disclosure is an active system, in that one or more sensors are utilized to determine one or more operating conditions and direct setting of the position of the modulating valve **74**. The sensors may include a pressure sensor **76** and/or a temperature sensor **78** located along the bleed duct **60**, upstream of the modulating valve **74**. The pressure sensor **76** and the temperature sensor **78** are configured to sense a pressure and a temperature, respectively, of the bleed airflow **66** directed from the high pressure compressor **52** through the bleed port **58**. The pressure sensor **76** and the temperature sensor **78** may be connected to a control system, such as a full authority digital engine control (FADEC) **80**, with the modulating valve **74** also operably connected to the FADEC **80**. During operation of the bleed air cooling system **72**, the FADEC **80** evaluates data from the pressure sensor **76** and/or the temperature sensor **78** to determine a selected position for the modulating valve **74**. In addition to, or as an alternative to pressure sensor **76** and/or temperature sensor **78**, the FADEC **80** may utilize any of a variety of engine operating characteristics, engine system positions, and/or any of a number of aircraft flight conditions or aircraft systems positions to determine the selected position for the modulating valve **74**. A command is then issued from the FADEC **80** to the modulating valve **74** to move the position

of the modulating valve **74** to the selected position between fully opened and fully closed. A feedback may be included to determine whether the modulating valve **74** reached the commanded position.
(15) While one bleed duct **60** delivering bleed airflow **66** to one turbine manifold **68** from a single bleed port **58** is shown in FIG. **2**, in other embodiments, the single bleed port **58** may be utilized to deliver bleed airflow **66** to two or more turbine manifolds **68**. Further, the bleed duct **60** may extend between any compressor **24** location, such as high pressure compressor **52**, low pressure compressor **44** or fan **42**, to any downstream location, such as high pressure turbine **54** or low pressure turbine **46**.
(16) In other embodiments, such as illustrated in FIG. **3**, multiple bleed ports **58** may be utilized, with a first bleed port **58***a* located at a first bleed location in the high pressure compressor **52** and a second bleed port **58***b* located at a second bleed location in the high pressure compressor with, for example, the first bleed port **58***a* located upstream of the second bleed port **58***b*, relative to a general direction of airflow through the high pressure compressor **52**.
(17) The first bleed port **58***a* delivers a first bleed airflow **66***a* to a first turbine manifold **68***a* via a first bleed duct **60***a*, while the second bleed port **58***b* similarly delivers a second bleed airflow **66***b* to a second turbine manifold **68***b* via a second bleed duct **60***b*. Each bleed duct **60***a*, **60***b* includes an independently operated modulating valve **74***a*, **74***b*, connected to the FADEC **80**, which utilizes one or more pressure sensors **76**, temperature sensors **78**, and/or other operational data to determine a selected position of each modulating valve **74***a*, **74***b*, and to command the modulating valves **74***a*, **74***b* to their respective selected positions. It is to be appreciated that while two bleed ports **58** and bleed ducts **60** are illustrated in the embodiment of FIG. **3**, other quantities of such assemblies, for example, three, four or five modulated bleed ducts **60** may be utilized in the bleed air cooling system **72**.
(18) Actively-controlled modulation of the bleed airflow **66** as disclosed herein allows for adaptability of the bleed airflow **66** delivered to the turbine section **28** based on data collected from sensors **76**, **78** regarding one or more conditions of the bleed airflow **66** entering the bleed duct **60** from the high pressure compressor **52**.
(19) The term “about” is intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application. For example, “about” can include a range of ±8% or 5%, or 2% of a given value.
(20) The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.
(21) While the present disclosure has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

Claims

1. A bleed air cooling system for a gas turbine engine, comprising: a bleed port disposed at an axial location of the gas turbine engine to divert a bleed airflow from a gas turbine engine flowpath; a bleed outlet disposed at a turbine section of the gas turbine engine; two or more turbine manifolds disposed at the turbine section extending completely around a perimeter of the turbine section, the two or more turbine manifolds configured to distribute the bleed airflow to multiple bleed outlet circumferential locations, a first turbine manifold of the two or more turbine manifolds axially spaced apart from a second turbine manifold of the two or more turbine manifolds; a bleed duct in fluid communication with the bleed port and configured to convey the bleed airflow from the bleed port to the bleed outlet; a modulating valve disposed at the bleed duct, movable between a fully opened position and a fully closed position to regulate the bleed airflow through the bleed duct based on one or more operating conditions of the gas turbine engine flowpath; one or more sensors disposed at the bleed duct to sense the one or more operating conditions, the modulating valve responsive to the one or more operating conditions sensed by the one or more sensors, the one or more sensors disposed between the bleed port and the modulating valve; a control system operably connected to the modulating valve and the one or more sensors, the control system configured to evaluate data from the one or more sensors to determine a selected position for modulating valve and command the modulating valve to the selected position; wherein the modulating valve is configured to be positioned anywhere between the fully opened position and the fully closed position; wherein the control system comprises a full-authority digital engine control (FADEC); wherein the one or more operating conditions are one or more properties of the bleed airflow entering the bleed port; and wherein the one or more sensors include a pressure sensor or a temperature sensor; wherein the bleed duct includes a radially-extending first portion, and axially extending second portion and a curvilinear transition portion connecting the first portion to the second portion; and wherein the one or more sensors are disposed in the transition portion.
2. The bleed air cooling system of claim 1, wherein the bleed airflow is diverted from a high pressure compressor of the gas turbine engine.
3. The bleed air cooling system of claim 1, further comprising a feedback to determine whether the modulating valve reached a commanded position.
4. The bleed air cooling system of claim 1, wherein the modulating valve is positioned along the bleed duct nearer to the bleed outlet than to the bleed port.
5. A gas turbine engine, comprising: a compressor section; a turbine section operably connected to the compressor section; and a bleed air cooling system, comprising: a bleed port disposed at the compressor section to divert a bleed airflow from a gas turbine engine flowpath; a bleed outlet disposed at the turbine section; two or more turbine manifolds disposed at the turbine section extending completely around a perimeter of the turbine section, the two or more turbine manifolds configured to distribute the bleed airflow to multiple bleed outlet circumferential locations, a first turbine manifold of the two or more turbine manifolds axially spaced apart from a second turbine manifold of the two or more turbine manifolds; a bleed duct in fluid communication with the bleed port and configured to convey the bleed airflow from the bleed port to the bleed outlet; a modulating valve disposed at the bleed duct, movable between a fully opened position and a fully closed position to regulate the bleed airflow through the bleed duct based on one or more operating conditions of the gas turbine engine flowpath; one or more sensors disposed at the bleed duct to sense the one or more operating conditions, the modulating valve responsive to the one or more operating conditions sensed by the one or more sensors, the one or more sensors disposed between the bleed port and the modulating valve; and a control system operably connected to the modulating valve and the one or more sensors, the control system configured to evaluate data from the one or more sensors to determine a selected position for modulating valve and command the modulating valve to the selected position; wherein the modulating valve is positioned along the bleed duct nearer to the bleed outlet than to the bleed port; and wherein the modulating valve is

configured to be positioned anywhere between the fully opened position and the fully closed position; wherein the control system comprises a full-authority digital engine control (FADEC); wherein the one or more operating conditions are one or more properties of the bleed airflow entering the bleed port; and wherein the one or more sensors include a pressure sensor or a temperature sensor; wherein the bleed duct includes a radially-extending first portion, and axially extending second portion and a curvilinear transition portion connecting the first portion to the second portion; and wherein the one or more sensors are disposed in the transition portion.

6. The gas turbine engine of claim 5, wherein the bleed airflow is diverted from a high pressure compressor of the gas turbine engine.

7. A method of cooling one or more components of a gas turbine engine, comprising: urging a bleed airflow through a bleed port disposed at a first axial location of a compressor section of the gas turbine engine; flowing the bleed airflow through a bleed duct toward a bleed outlet disposed at a turbine section of the gas turbine engine; two or more turbine manifolds disposed at the turbine section extending completely around a perimeter of the turbine section, the two or more turbine manifolds configured to distribute the bleed airflow to multiple bleed outlet circumferential locations, a first turbine manifold of the two or more turbine manifolds axially spaced apart from a second turbine manifold of the two or more turbine manifolds; sensing one or more operating conditions of the gas turbine engine flowpath via one or more sensors disposed at the bleed duct to sense the one or more operating conditions, the one or more sensors disposed between the bleed port and a modulating valve disposed in the bleed duct; evaluating data from the one or more sensors at a control system operably connected to the one or more sensors and the modulating valve; determining a selected position of the modulating valve via the control system in response to the data from the one or more sensors; and commanding the modulating valve to the selected position via the control system; wherein the modulating valve is configured to be positioned anywhere between a fully opened position and a fully closed position; wherein the control system comprises a full-authority digital engine control (FADEC); wherein the one or more operating conditions are one or more properties of the bleed airflow entering the bleed port; and wherein the one or more sensors include a pressure sensor or a temperature sensor; wherein the bleed duct includes a radially-extending first portion, and axially extending second portion and a curvilinear transition portion connecting the first portion to the second portion; and wherein the one or more sensors are disposed in the transition portion.