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Acoustic panel with active impedance control

Abstract

An acoustic system is provided that includes a face skin, a back skin and a cellular core arranged between the face skin and the back skin. The face skin includes a first member, a second member and a plurality of ports extending through the face skin. The first member includes a plurality of first perforations. The second member includes a plurality of second perforations and is configured to move along the first member. Each of the ports includes a respective one of the first perforations and a respective one of the second perforations. The cellular core includes a plurality of chambers. Each of the chambers extends between the face skin and the back skin. Each of the chambers is fluidly coupled with a respective one or more of the ports.

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Background/Summary

TECHNICAL FIELD

(1) This disclosure relates generally to an acoustic panel for, for example, an aircraft propulsion system.

BACKGROUND INFORMATION

(2) An aircraft propulsion system may include one or more acoustic panels for attenuating sound generated by its gas turbine engine. Various types and configurations of acoustic panels are known in the art. While these known acoustic panels have various benefits, there is still room in the art for improvement.

SUMMARY

(3) According to an aspect of the present disclosure, an acoustic system is provided that includes a face skin, a back skin and a cellular core arranged between the face skin and the back skin. The face skin includes a first member, a second member and a plurality of ports extending through the

face skin. The first member includes a plurality of first perforations. The second member includes a plurality of second perforations and is configured to move along the first member. Each of the ports includes a respective one of the first perforations and a respective one of the second perforations. The cellular core includes a plurality of chambers. Each of the chambers extends between the face skin and the back skin. Each of the chambers is fluidly coupled with a respective one or more of the ports.

(4) According to another aspect of the present disclosure, another acoustic system is provided that includes an acoustic panel and an actuation system. The acoustic panel includes a face skin, a back skin and a cellular core connected to the face skin and the back skin. The face skin includes a plurality of ports extending through the face skin. The face skin has an acoustic impedance. The cellular core includes a plurality of chambers. Each of the chambers extends from the face skin to the back skin. Each of the chambers is fluidly coupled with a respective one or more of the ports. The actuation system is operatively coupled with the acoustic panel. The actuation system is configured to manipulate the face skin to change the acoustic impedance during operation of the acoustic system.

(5) According to still another aspect of the present disclosure, a method is provided for sound attenuation. During this method, an acoustic parameter is monitored at an acoustic panel. A sensor signal is provided indicative of the acoustic parameter. The acoustic panel includes a face skin, a back skin and a cellular core connected to the face skin and the back skin. The face skin includes a plurality of ports extending through the face skin. The cellular core includes a plurality of chambers. Each of the chambers extends from the face skin to the back skin. Each of the chambers is fluidly coupled with a respective one or more of the ports. The face skin is manipulated to change an acoustic impedance of the face skin based on the sensor signal.

(6) The actuation system may be configured to manipulate the face skin to change a flow area of one or more of the ports.

(7) The face skin may include an exterior member and an interior member between the exterior member and the cellular core. The actuation system may be configured to move one of the exterior member or the interior member along another one of the exterior member or the interior member to change the acoustic impedance.

(8) The acoustic system may also include a sensor system configured to monitor an acoustic parameter and provide a sensor signal indicative of the acoustic parameter. The actuation system may be configured to manipulate the face skin based on the sensor signal.

(9) The second member may be configured to move along the first member to change an acoustic impedance of the face skin.

(10) The second member may be configured to move along the first member to change a flow area through each of the plurality of ports.

(11) A first of the ports may include a first of the first perforations and a first of the second perforations. The second member may be configured to move along the first member between a first position and a second position. The first of the second perforations may overlap the first of the first perforations a first percentage when the second member is in the first position. The first of the second perforations may overlap the first of the first perforations a second percentage when the second member is in the second position. The second percentage may be different than the first percentage.

(12) A first of the ports may include a first of the first perforations and a first of the second perforations. The first of the first perforations may have an elongated cross-sectional geometry. The first of the second perforations may have an elongated cross-sectional geometry.

(13) The second member may be configured to move along the first member in a first direction. A major axis of the first of the first perforations and a major axis of the first of the second perforations may be parallel with the first direction.

(14) The first member may be an exterior member of the face skin. The second member may be an

interior member of the face skin. The interior member may be disposed between the exterior member and the cellular core.
(15) The cellular core may be connected to the second member and the back skin.
(16) The first member may be an interior member of the face skin. The second member may be an exterior member of the face skin. The interior member may be disposed between the exterior member and the cellular core.
(17) The cellular core may be connected to the first member and the back skin.
(18) The acoustic system may also include an acoustic panel including the face skin, the back skin and the cellular core. The acoustic panel may extend axially along and circumferentially about a centerline. The second member may be configured to move in an axial direction along the first member.
(19) The acoustic system may also include an acoustic panel including the face skin, the back skin and the cellular core. The acoustic panel may extend axially along and circumferentially about a centerline. The second member may be configured to move in a circumferential direction along the first member.
(20) The acoustic system may also include an actuation system configured to move the second member along the first member.
(21) The acoustic system may also include a sensor system configured to monitor an acoustic parameter and provide a sensor signal indicative of the acoustic parameter. The actuation system may be configured to move the second member along the first member based on the sensor signal.
(22) A first of the chambers may extend un-interrupted through the cellular core from the face skin to the back skin.
(23) The cellular core may include a septum dividing a first of the chambers into a plurality of fluidly coupled sub-chambers.
(24) The acoustic system may also include a component of an aircraft propulsion system. The component may include the face skin, the back skin and the cellular core.
(25) The present disclosure may include any one or more of the individual features disclosed above and/or below alone or in any combination thereof.
(26) The foregoing features and the operation of the invention will become more apparent in light of the following description and the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a partial side sectional illustration of an acoustic panel for an acoustic system.
(2) FIG. **2** is a partial cross-sectional illustration of the acoustic panel.
(3) FIG. **3** is a partial side sectional illustration of an interior member of a face skin for the acoustic panel taken along line **3-3** in FIG. **4**.
(4) FIG. **4** is a partial illustration of the interior member of the face skin.
(5) FIG. **5** is a partial side sectional illustration of an exterior member of the face skin taken along line **5-5** in FIG. **6**.
(6) FIG. **6** is a partial illustration of the exterior member of the face skin.
(7) FIG. **7** is a partial perspective cutaway illustration of the acoustic panel.
(8) FIGS. **8**A-C are partial schematic illustrations of the acoustic system with the members of the face skin in various arrangements.
(9) FIGS. **9**A and **9**B are partial schematic sectional illustrations of the acoustic system with an actuation system coupled to and configured to move different members of the face skin.
(10) FIG. **10** is a partial side sectional illustration of the acoustic panel configured as a multi-degree of freedom acoustic panel.

(11) FIG. **11** is a schematic side sectional illustration of an aircraft propulsion system configured with one or more of the acoustic panels.

DETAILED DESCRIPTION

(12) FIGS. **1** and **2** are partial sectional illustrations of a structural, acoustic panel **20** for an acoustic system **22** (e.g., an active impedance control system) of an aircraft. This acoustic panel **20** may be configured to attenuate sound (e.g., noise) generated by a propulsion system of the aircraft. The aircraft propulsion system may be a turbofan propulsion system, a turbojet propulsion system, a turboprop propulsion system or any other ducted-rotor or open-rotor aircraft propulsion system. The acoustic panel **20** may be part of a housing (e.g., a nacelle) for an engine (e.g., a gas turbine engine) of the aircraft propulsion system. The acoustic panel **20**, for example, may be configured as or otherwise included as part of an inner barrel, an outer barrel, a translating sleeve, a blocker door, a bifurcation, etc. Alternatively, the acoustic panel **20** may be part of another component of the aircraft such as, but not limited to, an engine pylon, an aircraft wing or an aircraft fuselage. Furthermore, the acoustic panel **20** may also or alternatively be configured to attenuate aircraft related sound other than the sound generated by the aircraft propulsion system. However, for ease of description, the acoustic panel **20** may be described below as attenuating propulsion system sound and with respect to a component **24** (e.g., barrel) of the engine housing along a flowpath **26** (e.g., a bypass flowpath) within the aircraft propulsion system.

(13) Referring to FIG. **1**, the acoustic panel **20** extends axially along a centerline axis **28**. Briefly, this centerline axis **28** may be a centerline axis of the aircraft propulsion system, a centerline axis of the engine housing and/or a centerline axis of the component **24** (e.g., the barrel) which is formed by or otherwise includes the acoustic panel **20**. The acoustic panel **20** extends radially between and to a radial inner side **30** of the acoustic panel **20** and a radial outer side **32** of the acoustic panel **20**. Referring to FIG. **2**, the acoustic panel **20** extends circumferentially about (e.g., partially or completely around) the centerline axis **28**. The component **24** and/or its acoustic panel **20** may thereby have a curved (e.g., arcuate, cylindrical, conical, frustoconical) geometry. The present disclosure, however, is not limited to such an exemplary curved geometry.

(14) The acoustic panel **20** of FIGS. **1** and **2** includes a perforated face skin **34**, a solid (e.g., non-perforated) back skin **36** and a cellular core **38**. For ease of description, the face skin **34** is described below as an inner skin of the acoustic panel **20** and the back skin **36** is described below as an outer skin of the acoustic panel **20**. With such an arrangement, the acoustic panel **20** and its face skin **34** may form an outer peripheral boundary of at least a portion of the flowpath **26** within the aircraft propulsion system. It is contemplated, however, the face skin **34** may alternatively be the acoustic panel outer skin and the back skin **36** may alternatively be the acoustic panel inner skin. With such an arrangement, the acoustic panel **20** and its face skin **34** may form an inner peripheral boundary of at least a portion of the flowpath **26** within the aircraft propulsion system. The present disclosure, of course, is not limited to the foregoing exemplary arrangements. The acoustic panel **20**, for example, may form a circumferential side boundary of the flowpath **26** and/or may otherwise be located with the aircraft propulsion system and/or the aircraft.

(15) The face skin **34** of FIGS. **1** and **2** extends axially along and circumferentially about the centerline axis **28**. The face skin **34** has a radial thickness **40**. This face skin thickness **40** extends radially between and to opposing sides **42** and **44** of the face skin **34**, where the exterior side **42** of the face skin **34** is also the inner side **30** of the acoustic panel **20** of FIGS. **1** and **2**. The face skin thickness **40** may remain uniform (e.g., constant) as the face skin **34** extends axially along and/or circumferentially about the centerline axis **28**. The face skin **34** of FIGS. **1** and **2** includes a face skin interior member **46**, a face skin exterior member **48** and a plurality of face skin ports **50**.

(16) The interior member **46** may be configured as an interior layer, an interior panel or another sheet-like body that forms an interior portion of the face skin **34**. The interior member **46** of FIGS. **1** and **2**, for example, is formed by a relatively thin sheet or layer of material that extends axially along and circumferentially about the centerline axis **28**. This interior member material may be or

otherwise include a metal, a polymer (e.g., a thermoplastic or thermoset material) or a fiber reinforced composite (e.g., fiber reinforcement such as fiberglass, carbon fiber and/or aramid fibers within a polymer matrix). The interior member **46** has a radial thickness **52**. This interior member thickness **52** extends radially between and to the face skin interior side **44** and an exterior side **54** of the interior member **46** at an interface between the interior member **46** and the exterior member **48**.
(17) Referring to FIG. **3**, the interior member **46** includes a plurality of interior member perforations **56** ("interior perforations"); e.g., through-holes such as slots or slits. Each of these interior perforations **56** extends generally radially through the interior member **46** along a centerline **58** of the respective interior perforation **56** from the interior member exterior side **54** to the face skin interior side **44**. Referring to FIG. **4**, each interior perforation **56** may have an elongated cross-sectional geometry when viewed, for example, in a reference plane perpendicular to the interior perforation centerline **58**. The interior perforation **56** of FIG. **4**, for example, has a minor axis **60** and a major axis **62**, where a major axis dimension of the interior perforation **56** along the major axis **62** is larger than a minor axis dimension of the interior perforation **56** along the minor axis **60**. Example shapes of the elongated cross-sectional geometry include, but are not limited to, a polygon (e.g., a rectangle with rounded or sharp corners) and an oval. For ease of description, the major axis **62** is shown as being parallel with the centerline axis **28**. It is contemplated, however, the major axis **62** may alternatively be perpendicular to the centerline axis **28** or otherwise (e.g., non-zero acutely) angularly offset from the centerline axis **28** depending upon operation characteristics of the acoustic panel **20**.
(18) Referring to FIGS. **1** and **2**, the exterior member **48** may be configured as an exterior layer, an exterior panel or another sheet-like body that forms an exterior portion of the face skin **34**. The exterior member **48** of FIGS. **1** and **2**, for example, is formed by a relatively thin sheet or layer of material that extends axially along and circumferentially about the centerline axis **28**. This exterior member material may be or otherwise include a metal, a polymer (e.g., a thermoplastic or thermoset material) or a fiber reinforced composite (e.g., fiber reinforcement such as fiberglass, carbon fiber and/or aramid fibers within a polymer matrix). This exterior member material may be the same or different than the interior member material. The exterior member **48** has a radial thickness **64**. This exterior member thickness **64** extends radially between and to the face skin exterior side **42** and an interior side **66** of the exterior member **48** at the interface between the interior member **46** and the exterior member **48**. The exterior member thickness **64** of FIGS. **1** and **2** is equal to the interior member thickness **52**. However, for select acoustic panel applications, the exterior member thickness **64** may alternatively be different (e.g., larger or smaller) than the interior member thickness **52**.
(19) Referring to FIG. **5**, the exterior member **48** includes a plurality of exterior member perforations **68** ("exterior perforations"); e.g., through-holes such as slots or slits. Each of these exterior perforations **68** extends generally radially through the exterior member **48** along a centerline **70** of the respective exterior perforation **68** from the exterior member interior side **66** to the face skin exterior side **42**. Referring to FIG. **6**, each exterior perforation **68** may have an elongated cross-sectional geometry when viewed, for example, in a reference plane perpendicular to the exterior perforation centerline **70**. The exterior perforation **68** of FIG. **6**, for example, has a minor axis **72** and a major axis **74**, where a major axis dimension of the exterior perforation **68** along the major axis **74** is larger than a minor axis dimension of the exterior perforation **68** along the minor axis **72**. Example shapes of the elongated cross-sectional geometry include, but are not limited to, a polygon (e.g., a rectangle with rounded or sharp corners) and an oval. For ease of description, the major axis **74** is shown as being parallel with the centerline axis **28**. It is contemplated, however, the major axis **74** may alternatively be perpendicular to the centerline axis **28** or otherwise (e.g., non-zero acutely) angularly offset from the centerline axis **28** depending upon operation characteristics of the acoustic panel **20**. In general, the exterior perforation cross-sectional geometry and relative orientation of FIG. **6** is the same as the interior perforation cross-

sectional geometry and relative orientation of FIG. **4**. However, for select acoustic panel applications, the exterior perforation cross-sectional geometry may be different than (e.g., but, complimentary to) the interior perforation cross-sectional geometry.

(20) Referring to FIGS. **1** and **2**, the interior member **46** and the exterior member **48** are arranged together to form the face skin **34**. The interior member **46** may extend axially and circumferentially along (e.g., a portion or an entirety of) the exterior member **48**. The exterior member **48** may extend axially and circumferentially along (e.g., a portion or an entirety of) the interior member **46**. The face skin members **46** and **48** thereby configure at least a portion or an entirety of the face skin **34** as a multi-layered structure; e.g., a dual layered structure. However, as discussed below in further detail, the face skin members **46** and **48** are configured to move (e.g., slide, translate, etc.) relative to one another.

(21) Each of the face skin ports **50** extends generally radially through the face skin **34** from the face skin exterior side **42** to the face skin interior side **44**. Each face skin port **50** of FIGS. **1** and **2**, for example, includes a respective one of the interior perforations **56** and a respective one of the exterior perforations **68**. More particularly, each interior perforation **56** may extend radially through the interior member **46** from the face skin interior side **44** to the respective exterior perforation **68**. Similarly, each exterior perforation **68** may extend radially through the exterior member **48** from the face skin exterior side **42** to the respective interior perforation **56**. Thus, each interior perforation **56** is axially and circumferentially aligned with and fluidly coupled with a respective one of the exterior perforations **68** to form a respective one of the face skin ports **50** through the face skin **34**. Note, as discussed below in further detail, the specific alignment between the interior perforations **56** and the exterior perforations **68** may change during acoustic panel operation, engine operation or more generally aircraft operation.

(22) The back skin **36** of FIGS. **1** and **2** formed by a relatively thin sheet or layer of (e.g., continuous and uninterrupted) material that extends axially along and circumferentially about the centerline axis **28**. This back skin material may be the same as or different than the interior member material and/or the exterior member material. The back skin material, for example, may be or otherwise include a metal, a polymer (e.g., a thermoplastic or thermoset material) or a fiber reinforced composite (e.g., fiber reinforcement such as fiberglass, carbon fiber and/or aramid fibers within a polymer matrix). The back skin **36** has a radial thickness **76**. This back skin thickness **76** extends radially between opposing sides **78** and **80** of the back skin **36**, where the exterior side **80** of the back skin **36** is also the outer side **32** of the acoustic panel **20** of FIGS. **1** and **2**. The back skin thickness **76** may remain uniform (e.g., constant) as the back skin **36** extends axially along and/or circumferentially about the centerline axis **28**. The back skin thickness **76** of FIGS. **1** and **2** may be equal to the interior member thickness **52** and/or the exterior member thickness **64**.

(23) The cellular core **38** is arranged and extends radially between the face skin **34** and the back skin **36**. The cellular core **38** may also be connected to (a) the face skin **34** and its interior member **46** and/or (b) the back skin **36**. The cellular core **38**, for example, may be welded, brazed, fused, adhered and/or otherwise bonded to the interior member **46** and/or the back skin **36**. The cellular core **38** of FIGS. **1** and **2** extends axially along and circumferentially about the centerline axis **28**. The cellular core **38** has a radial depth **82**. This cellular core depth **82** extends radially between and to the face skin **34** at its interior side **44** and the back skin **36** at its interior side **78**. The cellular core depth **82** may remain uniform (e.g., constant) as the cellular core **38** extends axially along and/or circumferentially about the centerline axis **28**. The cellular core depth **82** may be substantially larger than the face skin thickness **40** and/or the back skin thickness **76**. The cellular core depth **82**, for example, may be at least ten to forty times (10-40×), or more, larger than the face skin thickness **40** and/or the back skin thickness **76**. The cellular core **38** of the present disclosure, however, is not limited to such an exemplary dimensional relationship and may vary based on sound attenuation requirements, space requirements, etc.

(24) The cellular core **38** of FIGS. **1** and **2** is configured with one or more core chambers **84** (e.g.,

internal chambers, acoustic resonance chambers, internal cavities, etc.) radially between the face skin **34** and the back skin **36**. Referring to FIG. **7**, the cellular core **38** may be configured as a honeycomb core. The cellular core **38** of FIG. **7**, for example, includes a plurality of corrugated sidewalls **86**. These corrugated sidewalls **86** are arranged in a side-by-side array and are connected to one another such that each neighboring (e.g., adjacent) pair of the corrugated sidewalls **86** forms an array of the core chambers **84** laterally (e.g., circumferentially or axially) therebetween. The cellular core **38** and its corrugated sidewalls **86** may be constructed from or otherwise include a core material such as metal; e.g., sheet metal. The present disclosure, however, is not limited to such an exemplary cellular core construction nor material.
(25) Each core chamber **84** of FIGS. **1** and **2** extends radially within/through the cellular core **38** along a respective centerline **88** of the respective core chamber **84** between and to the face skin **34** at its face skin interior side **44** and the back skin **36** at its back skin interior side **78**. One or more or all of the core chambers **84** may thereby each (e.g., axially and circumferentially) overlap and be fluidly coupled with a respective set of one or more of the face skin ports **50** and their respective interior perforations **56**. Referring to FIG. **7**, each of the core chambers **84** has a cross-sectional geometry (e.g., shape, size, etc.) when viewed in a reference plane; e.g., a plane perpendicular to the chamber centerline **88** of the respective core chamber **84**. This chamber cross-sectional geometry may have a polygonal shape (e.g., a hexagonal shape, a rectangular shape, a triangular shape, etc.) or a free form shape. The present disclosure, however, is not limited to foregoing exemplary cellular core configuration. For example, one or more or all of the core chambers **84** may alternatively each have a circular, elliptical or other non-polygonal cross-sectional geometry. Furthermore, various other types of honeycomb cores and, more generally, various other types of cellular cores for an acoustic panel are known in the art, and the present disclosure is not limited to any particular ones thereof.
(26) The acoustic panel **20** of FIGS. **1** and **2** is configured as a single-degree of freedom (SDOF) acoustic panel. One or more or all of the core chambers **84** of FIGS. **1** and **2**, for example, each extends radially uninterrupted between and to the face skin **34** and the back skin **36**. With such an arrangement, the acoustic panel **20** may be tuned to attenuate, for example, a select frequency of sound, which tuning may be based on a radial height of each core chamber **84**/the cellular core depth **82**.
(27) During operation of the acoustic panel **20** of FIGS. **1** and **2**, sound waves may enter a core chamber **84** through the respective face skin port(s) **50**. These sound waves may travel through the core chamber **84** and reflect against the back skin **36**. The reflected sound waves may travel back through the core chamber **84** and exit the acoustic panel **20** through the respective face skin port(s) **50**, where those reflected sound waves may be out of phase from and destructively interfere with incoming soundwaves; i.e., pressure waves. Of course, the sound waves may also or alternatively reflect against one or more other elements of the acoustic panel **20** which may further influence sound attenuation. Moreover, sound attenuation may be influenced by frictional losses in the face skin ports **50** (e.g., when pressure waves move in and out of the face skin ports **50** as the chambers **84** are energized and the acoustic panel **20** operates about its resonance frequency(ies)) thus converting the mechanical energy into heat dissipation.
(28) During an aircraft flight, the propulsion system engine may operate at various different power settings. For example, during aircraft takeoff and/or climb, the propulsion system engine may operate at a relatively high power setting. During aircraft flyover, the propulsion system engine may operate at an intermediate (e.g., mid) power setting. During aircraft approach and/or landing, the propulsion system engine may operate at a relatively low power setting. Each of these engine power settings, as well as various power settings in between, may be associated with its own sound pressure level (SPL). For example, at the high power setting, the propulsion system engine and its propulsor rotor (e.g., a fan rotor) may generate a relatively high sound pressure level. At the intermediate power setting, the propulsion system engine and its propulsor rotor (e.g., a fan rotor)

may generate an intermediate sound pressure level. At the low power setting, the propulsion system engine and its propulsor rotor (e.g., a fan rotor) may generate a relatively low sound pressure level.
(29) A flow resistance (R) along the acoustic panel **20** may non-linearly increase as the sound pressure level of the sound waves increases. Generally speaking, the higher the flow resistance, the less permeable a fluid such as air is through a porous material such as the face skin **34**. Thus, optimum acoustic panel characteristics like acoustic flow resistance depend on the sound pressure level. Acoustic properties or characteristics of the acoustic panel **20** may therefore be changed (e.g., adapted, adjusted) to effectively respond to and attenuate a lower or higher sound pressure level. For example, the acoustic properties/characteristics of the acoustic panel **20** may be changed to provide (or move closer to) an optimum flow resistance for each sound pressure level and flow (e.g., Mach number in the flowpath **26**) operating condition.
(30) Parameters associated with the face skin ports **50** may affect the capability of the acoustic panel **20** to attenuate sound as well as aerodynamic characteristics of the acoustic panel **20**. For example, the acoustic panel **20** and, more particularly, the face skin **34** of FIGS. **8**A-C have a percentage of open area (POA). The term "percentage of open area" may describe a percentage of a surface area of an element that is occupied by open area; e.g., voids from the face skin ports **50**. This open area may be defined by a sum of flow areas **90** through the face skin **34**. The term "flow area" may describe a minimum flow area (e.g., a throat) through a respective face skin port **50**. This flow area **90** represents an area of (e.g., axial and circumferential) overlap between each exterior perforation **68** and a respective one of the interior perforations **56**. Where the overlap between the face skin perforations **56** and **68** increases (e.g., see FIG. **8**A), the flow area **90** increases. As the percentage of open area of the face skin **34** increases (e.g., see FIG. **8**A), the face skin **34** becomes more permeable to a flow of fluid such as air. Conversely, where the overlap between the face skin perforations **56** and **68** decreases (e.g., see FIG. **8**C), the flow area **90** decreases. As the percentage of open area of the face skin **34** decreases (e.g., see FIG. **8**C), the face skin **34** becomes less permeable to the flow of fluid. The face skin members **46** and **48** may thereby be arranged relative to one another to provide a select (e.g., optimum, enhanced, etc.) complex acoustic impendence (Z) value for the high, the intermediate and the low power settings as well as various power settings in-between.
(31) When the propulsion system engine is operating at a relatively high power setting with a relatively high sound pressure level, the face skin members **46** and **48** may be arranged at a first position (e.g., a fully open and/or maximum POA position) as shown in FIG. **8**A. At this first position, the face skin **34** may have a relatively high percentage of open area; e.g., 90-100% of maximum POA for the acoustic panel **20**. For example, a relatively high percentage (e.g., 90-100%) of each exterior perforation **68** may overlap a respective one of the interior perforations **56**. Similarly, a relatively high percentage (e.g., 90-100%) of each interior perforation **56** may also or alternatively overlap a respective one of the exterior perforations **68**. The flow area **90** through each face skin port **50** may thereby be sized to optimize the complex acoustic impendence (Z) value for the high sound pressure level associated with high power setting operation. The present disclosure, however, is not limited to the foregoing exemplary overlap percentages as these percentages may vary based on perforation size, shape as well as other engine operating parameters.
(32) When the propulsion system engine is operating at an intermediate power setting with an intermediate sound pressure level, the face skin members **46** and **48** may be arranged at a second position (e.g., intermediate position) as shown in FIG. **8**B. At this second position, the face skin **34** may have an intermediate percentage of open area; e.g., 80-90% of maximum POA for the acoustic panel **20**. For example, an intermediate percentage (e.g., 80-90%) of each exterior perforation **68** may overlap a respective one of the interior perforations **56**. Similarly, an intermediate percentage (e.g., 80-90%) of each interior perforation **56** may also or alternatively overlap a respective one of the exterior perforations **68**. The flow area **90** through each face skin port **50** may thereby be sized to optimize the complex acoustic impendence (Z) value for the intermediate sound pressure level

associated with intermediate power setting operation. The present disclosure, however, is not limited to the foregoing exemplary overlap percentages as these percentages may vary based on perforation size, shape as well as other engine operating parameters.

(33) When the propulsion system engine is operating at a relatively low power setting with a relatively low sound pressure level, the face skin members **46** and **48** may be arranged at a third position (e.g., a fully restricted and/or minimum PA position) as shown in FIG. **8**C. At this third position, the face skin **34** may have a relatively low percentage of open area; e.g., 50-70% of maximum POA for the acoustic panel **20**. For example, a relatively low percentage (e.g., 50-70%) of each exterior perforation **68** may overlap a respective one of the interior perforations **56**. Similarly, a relatively low percentage (e.g., 50-70%) of each interior perforation **56** may also or alternatively overlap a respective one of the exterior perforations **68**. The flow area **90** through each face skin port **50** may thereby be sized to optimize the complex acoustic impendence (Z) value for the low sound pressure level associated with low power setting operation. The present disclosure, however, is not limited to the foregoing exemplary overlap percentages as these percentages may vary based on perforation size, shape as well as other engine operating parameters.

(34) To rearrange the face skin members **46** and **48** relative to one another, the acoustic panel **20** of FIGS. **8**A-C is configured with an actuation system **92**. This actuation system **92** is operatively coupled to the face skin **34** and one of its face skin members **46**, **48**—an actuatable face skin member. For example, referring to FIG. **9**A, the actuation system **92** may be (e.g., directly or indirectly) connected to the interior member **46**; here, the actuatable face skin member. The exterior member **48** may be grounded (e.g., fixed) to another stationary support or frame of the aircraft. The actuation system **92** may thereby move (e.g., slide, translate, etc.) the interior member **46** (and elements **36** and **38**) along the exterior member **48**. In another example, referring to FIG. **9**B, the actuation system **92** may be (e.g., directly or indirectly) connected to the exterior member **48**; here, the actuatable face skin member. The interior member **46** (and elements **36** and **38**) may be grounded (e.g., fixed) to another stationary support or frame of the aircraft. The actuation system **92** may thereby move (e.g., slide, translate, etc.) the exterior member **48** along the interior member **46**.

(35) For ease of description, the movement of the actuatable face skin member **46**, **48** is shown in FIGS. **8**A-C as axial movement along the centerline axis **28**. However, the movement may alternatively be circumferential movement about the centerline axis **28**. Still alternatively, the movement may include both an axial and circumferential component; e.g., the actuatable face skin member **46**, **48** may spiral along and about the centerline axis **28**.

(36) The acoustic system **22** of FIGS. **9**A and **9**B may also include a sensor system **94**. This sensor system **94** is configured to monitor (e.g., measure or otherwise determine) one or more acoustic parameters at the acoustic panel **20** and its face skin **34** using sensors **96**. Examples of the acoustic parameters include, but are not limited to, a sound pressure level at the face skin **34** and an acoustic impendence at the face skin **34** and at the back skin **36**. Examples of the sensors **96** include, but are not limited to, microphones, pressure transducers, and pressure probes.

(37) The sensor system **94** of FIGS. **9**A and **9**B is also configured to provide (e.g., generate and output) a sensor signal indicative of the one or more acoustic parameters, for example, from each sensor **96**. Based on these sensor signals, the actuation system **92** may move the actuatable face skin member **46**, **48**. For example, a controller **98** (incorporated into or discrete from the actuation system **92**) may receive the sensor signals and process the sensor signals to provide a control signal. More particularly, the controller **98** is programmed to process the sensor signals to educe a measured impedance. The controller **98** may compare the measured impedance (Z.sub.meas) to an optimum impedance (Z.sub.opt) to generate the control signal, which control signal may be in the form of an output signal or power from the controller **98** to drive the actuation system **92**. This control signal may be proportional to intended adjustment to the percentage of open area to the fan skin **34**.

(38) The actuation system **92** may move the actuatable face skin member **46**, **48** in response to the control signal. With this operability, the actuatable face skin member **46**, **48** may be moved to provide a select (e.g., optimal) percentage of open area/a select (e.g., optimal) acoustic impedance for the sound pressure level measured at the acoustic panel **20**. Of course, the control signal may also be generated based on another acoustic parameter such as the acoustic impedance at the acoustic panel **20**. For example, the controller **98** may utilize feedback to determine if the predicted acoustic impedance is equal to or close to the measured acoustic impedance. The acoustic system **22** may thereby provide tuned (e.g., optimized) acoustic attenuation across various different operating conditions/phases of aircraft flight. By contrast, a typical prior art acoustic panel is tuned for a specific operating condition/phase of flight, and settles for sub-optimal operation at other operating conditions/phases of flight.
(39) The controller **98** may process the sensor signal using models and/or look-up tables. The controller **98** may thereby provide the control signal based on the sensor signal (e.g., measurements) as well as operating conditions of the propulsion system engine. Examples of the engine operating conditions include, but are not limited to, the engine power setting, a rotational speed of an engine rotor, a speed of the aircraft, and a temperature of ambient air.
(40) The acoustic panel **20** is described above as a single-degree of freedom acoustic panel for ease of description. The present disclosure, however, is not limited to such an exemplary acoustic panel configuration. For example, referring to FIG. **10**, the acoustic panel **20** may alternatively be configured as a multi-degree of freedom (MDOF) acoustic panel such as, but not limited to, a double-degree of freedom (DDOF) acoustic panel. One or more or all of the core chambers **84** of FIG. **10**, for example, is provided with at least (or only) one respective septum **100**; e.g., a perforated and/or porous member. Each septum **100** extends laterally across the respective core chamber **84** to divide that core chamber **84** into a plurality of sub-chambers **84**A and **84**B. These sub-chambers **84**A and **84**B are fluidly coupled with one another (e.g., radially) across the respective septum **100** through one or more perforations **102** (or pores) in that septum **100**. With such an arrangement, the acoustic panel **20** may be tuned to attenuate multiple frequencies of sound or to widen a frequency band of attenuation, which tuning may be based on the radial height of each core chamber **84**/the cellular core depth **82**, a radial distance between each septum **100** and the face skin **34** as well as the flow resistance (R) for each layer.
(41) During operation of the acoustic panel **20** of FIG. **10**, sound waves may enter a core chamber **84** through the respective face skin port(s) **50**. Some of these sound waves may travel through the near sub-chamber **84**A and reflect against solid portion(s) of the septum **100**. The reflected sound waves may travel back through the near sub-chamber **84**A and exit the acoustic panel **20** through the respective face skin port(s) **50**, where those reflected sound waves may be out of phase from and destructively interfere with incoming soundwaves of a first frequency. Other sound waves may pass through porous portion(s) of the septum **100** and travel through the far sub-chamber **84**B and reflect against the back skin **36**. The reflected sound waves may travel back through the far sub-chamber **84**B, across the septum **100**, through the near sub-chamber **84**A and exit the acoustic panel **20** through the respective face skin port(s) **50**, where those reflected sound waves may be out of phase from and destructively interfere with other incoming soundwaves of a second frequency. Of course, the sound waves may also or alternatively reflect against one or more other elements of the acoustic panel **20** which may further influence sound attenuation.
(42) FIG. **11** illustrates an example of the aircraft propulsion system with which the one or more of the acoustic panels **20** may be configured. This aircraft propulsion system includes a turbofan gas turbine engine **104**. The gas turbine engine **104** of FIG. **11** extends axially along the centerline axis **28** between an upstream airflow inlet **106** and a downstream airflow exhaust **108**. The gas turbine engine **104** includes a fan section **110**, a compressor section **111**, a combustor section **112** and a turbine section **113**. The turbine section **113** includes a high pressure turbine (HPT) section **113**A and a low pressure turbine (LPT) section **113**B, which LPT section **113**B may also be referred to as

a power turbine (PT) section.
(43) The engine sections **110-113**B are arranged within the engine housing **116**. This engine housing **116** includes an inner housing structure **118** and an outer housing structure **120**. The inner housing structure **118** may house one or more of the engine sections **111-113**B; e.g., a core of the gas turbine engine **104**. The outer housing structure **120** may house at least the fan section **110**. The inner and the outer housing structures **118** and **20** of FIG. **11** also form a bypass duct. The inner and/or the outer housing structure **120** may each include one or more of the acoustic panels **20**.
(44) Each of the engine sections **110**, **111**, **113**A and **113**B includes a respective bladed rotor **122-125**. Each of these bladed rotors **122-125** includes a plurality of rotor blades arranged circumferentially around and connected to one or more respective rotor disks. The rotor blades, for example, may be formed integral with or mechanically fastened, welded, brazed, adhered and/or otherwise attached to the respective rotor disk(s).
(45) The fan rotor **122** is connected to and driven by the LPT rotor **125** through a low speed shaft **128**. The compressor rotor **123** is connected to and driven by the HPT rotor **124** through a high speed shaft **130**. The shafts **128** and **130** are rotatably supported by a plurality of bearings (not shown). Each of these bearings is connected to the engine housing **116** by at least one stationary structure.
(46) During operation, air enters the gas turbine engine **104** through the airflow inlet **106**. This air is directed through the fan section **110** and into a core flowpath **132** and a bypass flowpath **134** (e.g., the flowpath **26**). The core flowpath **132** extends sequentially through the engine sections **111-113**B. The air within the core flowpath **132** may be referred to as “core air”. The bypass flowpath **134** extends through the bypass duct, which bypasses the engine core. The air within the bypass flowpath **134** may be referred to as “bypass air”.
(47) The core air is compressed by the compressor rotor **123** and directed into a combustion chamber **136** of a combustor **138** in the combustor section **112**. Fuel is injected into the combustion chamber **136** and mixed with the compressed core air to provide a fuel-air mixture. This fuel air mixture is ignited and combustion products thereof flow through and sequentially cause the HPT rotor **124** and the LPT rotor **125** to rotate. The rotation of the HPT rotor **124** drives rotation of the compressor rotor **123** and, thus, compression of the air received from a core airflow inlet. The rotation of the LPT rotor **125** drives rotation of the fan rotor **122**, which propels the bypass air through and out of the bypass flowpath **134**. The propulsion of the bypass air may account for a majority of thrust generated by the gas turbine engine **104**.
(48) The acoustic system **22** and its acoustic panel **20** may be included in various gas turbine engines other than the one described above. The acoustic system **22** and its acoustic panel **20**, for example, may be included in a geared gas turbine engine where a geartrain connects one or more shafts to one or more rotors in a fan section, a compressor section and/or any other engine section. Alternatively, the acoustic system **22** and its acoustic panel **20** may be included in a gas turbine engine configured without a geartrain; e.g., a direct drive gas turbine engine. The acoustic system **22** and its acoustic panel **20** may be included in a gas turbine engine configured with a single spool, with two spools (e.g., see FIG. **11**), or with more than two spools. The gas turbine engine may be configured as a turbofan engine, a turbojet engine, a turboprop engine, a turboshaft engine, a propfan engine, a pusher fan engine or any other type of gas turbine engine. The gas turbine engine may alternatively be configured as an auxiliary power unit (APU). The present disclosure therefore is not limited to any particular types or configurations of gas turbine engines. Furthermore, while the acoustic system **22** and its acoustic panel **20** is described above with respect to various aircraft applications, the acoustic system **22** and its acoustic panel **20** of the present application may alternatively be used for non-aircraft applications.
(49) While various embodiments of the present disclosure have been described, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible within the scope of the disclosure. For example, the present disclosure as described herein includes

several aspects and embodiments that include particular features. Although these features may be described individually, it is within the scope of the present disclosure that some or all of these features may be combined with any one of the aspects and remain within the scope of the disclosure. Accordingly, the present disclosure is not to be restricted except in light of the attached claims and their equivalents.

Claims

1. A method for sound attenuation, comprising: monitoring an acoustic parameter at an acoustic panel and providing a sensor signal indicative of the acoustic parameter within a cellular core, wherein the acoustic panel includes a face skin, a back skin and the cellular core connected to the face skin and the back skin, the face skin comprises a plurality of ports extending through the face skin, the cellular core comprises a plurality of chambers, each of the plurality of chambers extends from the face skin to the back skin, and each of the plurality of chambers is fluidly coupled with a respective one or more of the plurality of ports; and manipulating the face skin to change an acoustic impedance of the face skin based on the sensor signal.
2. An acoustic system, comprising: a face skin including a first member, a second member and a plurality of ports extending through the face skin, the first member comprising a plurality of first perforations, the second member comprising a plurality of second perforations and configured to move along the first member, and each of the plurality of ports including a respective one of the plurality of first perforations and a respective one of the plurality of second perforations; an actuation system configured to move the second member along the first member; a back skin; and a cellular core arranged between the face skin and the back skin, the cellular core comprising a plurality of chambers, each of the plurality of chambers extending between the face skin and the back skin, and each of the plurality of chambers fluidly coupled with a respective one or more of the plurality of ports; wherein the second member is configured to spiral along and about a centerline axis to change an acoustic impedance of the face skin.