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(54) Title: SYSTEMS AND METHODS OF SUPPRESSION OF GROUND VORTICES IN AIRCRAFT ENGINES

(57) Abstract: The present disclosure generally relates to systems and methods for inhibiting formation of ground vortices about a nacelle of an aircraft. The present disclosure can include a nacelle including a plurality of ports. The plurality of ports can extend through the nacelle from an exterior surface to an interior surface. The plurality of ports can be configured to direct a fluid from the exterior surface to an interior of the nacelle, inhibiting formation of ground vortices. Ports can be passive ports, such that a passive port can direct a fluid from the exterior surface to the interior based on a difference in pressure. The nacelle can further include one or more shields configured to block fluid flow through at least a portion of ports of the plurality of ports. The one or more shields can be configured to block a flow of a fluid due to a mechanical actuation.

SYSTEMS AND METHODS OF SUPPRESSION OF GROUND VORTICES IN AIRCRAFT ENGINES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 63/600,681, filed on November 18, 2023, which is incorporated herein by reference in its entirety as if fully set forth below.

FIELD OF THE DISCLOSURE

[0002] The various embodiments of the present disclosure relate generally to systems and methods for suppressing ground vortices in aircraft engines, and specifically to systems and methods for altering aerodynamic bleed to suppress ground vortices in aircraft engines.

BACKGROUND

[0003] Engine nacelles of commercial aircrafts must be designed to comply with the Code of Federal Regulations (CFRs) throughout all stages of flight including ground taxi, takeoff, climb, cruise, descent, and landing. Although a significant portion of the flight duration is spent in cruise, the critical design of the nacelle must accommodate operation at lower aircraft speeds during takeoff, landing, and ground operations when the performance of the engines can be strongly impacted by crosswind that can significantly alter the air intake at the inlet. At low speed, the crosswind can lead to the formation of a fuselage vortex and induce inlet flow separation (even away from the ground) and near the surface can form a ground vortex.

[0004] Once formed, this ground vortex induces distortion within the engine face and can also lead to the ingestion of foreign objects into the engine. Klein (1953) observed that, at the time, about 50% of all engines removed from aircraft for maintenance or repair had been damaged by foreign object ingestion which costs the airline industry an estimated \$3.8 billion per year today. This vortex can also introduce distortion into the inlet flow which can give rise to premature inlet flow separation and fan blade vibrations.

[0005] Traditional systems and methods have been directed towards utilizing a screen over the inlet to the engine to mitigate the effects of the ground vortex. This screen induces a significant drag on each engine, negatively affecting performance. Other traditional systems and methods attempt to eject air out of the engine, or nacelle, by using one or more jets to pump air from

within the nacelle to the exterior. These jets, however, not only take up a large volume of the nacelle inflow, but also require an active energy source for power.

[0006] Accordingly, there is a need for improved systems and methods to suppress such ground vortices.

BRIEF SUMMARY

[0007] An exemplary embodiment of the present disclosure provides a nacelle including an exterior surface; an interior surface; an interior; and a plurality of ports extending through the nacelle from the exterior surface to the interior surface. The plurality of ports can be configured to direct a fluid from the exterior surface to the interior, such that directing the fluid from the exterior surface to the interior inhibits formation of ground vortices.

[0008] In any of the embodiments disclosed herein, the plurality of ports can be configured to direct the fluid from the exterior surface to the interior based at least in part on a pressure difference of the fluid between the exterior surface and the interior surface.

[0009] In any of the embodiments disclosed herein, the plurality of ports can be an array of ports with a porosity between approximately 5% and approximately 50%.

[0010] In any of the embodiments disclosed herein, the nacelle can further include a bottom portion in proximity to a ground plane; and a top portion opposing the bottom portion. At least a portion of the plurality of ports can be located in the top portion.

[0011] In any of the embodiments disclosed herein, the top portion can be defined as an azimuthal top two thirds portion of the nacelle.

[0012] In any of the embodiments disclosed herein, at least one port of the plurality of ports can be a passive port.

[0013] In any of the embodiments disclosed herein, the nacelle can further include one or more shields. The one or more shields can be configured to block fluid flow through at least a portion of ports of the plurality of ports.

[0014] In any of the embodiments disclosed herein, the one or more shields can be located on one of the interior surface and the exterior surface of the nacelle.

[0015] In any of the embodiments disclosed herein, the one or more shields can be configured to block a flow of the fluid due to a mechanical actuation.

[0016] In any of the embodiments disclosed herein, the mechanical actuation can include an azimuthal shift of the one or more shields.

[0017] In any of the embodiments disclosed herein, the mechanical actuation can be prompted by a user input.

[0018] In any of the embodiments disclosed herein, the mechanical actuation can be autonomously triggered based at least in part on one or more flight factors, the one or more flight factors may include wind direction, wind speed, air pressure change, engine efficiency, internal-external nacelle pressure difference, aircraft speed, flight duration, flight altitude, engine fan speed, engine thrust, or any combination thereof.

[0019] In any of the embodiments disclosed herein, the mechanical actuation can be based at least in part on a flight phase, wherein the flight phase is selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

[0020] In any of the embodiments disclosed herein, the one or more shields can be configured such that the mechanical actuation may cause the one or more shields to transition among one or more configurations selected from a group consisting of: an open configuration, in which the one or more shields can be positioned such that fluid may flow through each port of the plurality of ports; a partially open configuration, in which the one or more shields can be positioned to block fluid flow through at least a portion of ports of the plurality of ports; and a closed configuration, in which the one or more shields can be positioned to block fluid flow through each port of the plurality of ports.

[0021] In any of the embodiments disclosed herein, a desired configuration of the one or more shields can be selected based at least in part on a flight phase. The flight phase can be selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

[0022] In any of the embodiments disclosed herein, the nacelle can further include an inlet, wherein the inlet can be configured to receive a main fluid flow, wherein the main fluid flow can be characterized by having an interior flow direction from a first end to a second end of the nacelle, and wherein the plurality of ports can be configured to direct the fluid, at least partially, in the interior flow direction.

[0023] In any of the embodiments disclosed herein, the plurality of ports can extend, at least partially, in the interior flow direction.

[0024] In any of the embodiments disclosed herein, at least one port of the plurality of ports can include a first section proximal to the exterior surface; and a second section proximal to the interior surface. The first section can extend substantially radially towards a centerline of the nacelle. The second section can extend, at least partially, in the interior flow direction.

[0025] An exemplary embodiment of the present disclosure provides a nacelle including an exterior surface; an interior surface; an interior; and a plurality of ports. The plurality of ports can include an array of ports distributed azimuthally about at least a portion of the nacelle. The array of ports can span a top portion of the nacelle. When a fluid comes into contact with the exterior surface, the plurality of ports can be configured to direct the fluid from the exterior surface to the interior of the nacelle.

[0026] In any of the embodiments disclosed herein, the nacelle can further include one or more shields. The one or more shields can be configured to block fluid flow through at least a portion of ports of the plurality of ports.

[0027] In any of the embodiments disclosed herein, the one or more shields can be located on one of the interior surface and the exterior surface of the nacelle.

[0028] In any of the embodiments disclosed herein, the one or more shields can be configured to block a flow of the fluid due to a mechanical actuation.

[0029] In any of the embodiments disclosed herein, the mechanical actuation can include an azimuthal shift of the one or more shields.

[0030] In any of the embodiments disclosed herein, the mechanical actuation can be prompted by a user input.

[0031] In any of the embodiments disclosed herein, the mechanical actuation can be autonomously triggered based at least in part on one or more flight factors, the one or more flight factors can include wind direction, wind speed, air pressure change, engine efficiency, internal-external nacelle pressure difference, aircraft speed, flight duration, flight altitude, engine fan speed, engine thrust, or any combination thereof.

[0032] In any of the embodiments disclosed herein, the mechanical actuation can be based at least in part on a flight phase, wherein the flight phase can be selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

[0033] In any of the embodiments disclosed herein, the one or more shields can be configured such that the mechanical actuation causes the one or more shields to transition among one or more configurations selected from a group consisting of: an open configuration, in which the one or more shields can be positioned such that fluid may flow through each port of the plurality of ports; a partially open configuration, in which the one or more shields can be positioned to block fluid flow through at least a portion of ports of the plurality of ports; and a closed

configuration, in which the one or more shields can be positioned to block fluid flow through each port of the plurality of ports.

[0034] In any of the embodiments disclosed herein, a desired configuration of the one or more shields can be selected based at least in part on a flight phase. The flight phase can be selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

[0035] In any of the embodiments disclosed herein, the nacelle can further include an inlet. The inlet can be configured to receive a main fluid flow. The main fluid flow can be characterized by having an interior flow direction from a first end to a second end of the nacelle. The plurality of ports can be configured to direct the fluid, at least partially, in the interior flow direction.

[0036] In any of the embodiments disclosed herein, at least one port of the plurality of ports can extend, at least partially, in the interior flow direction.

[0037] In any of the embodiments disclosed herein, at least one port of the plurality of ports can include: a first section proximal to the exterior surface; and a second section proximal to the interior surface. The first section can extend substantially radially to a centerline of the nacelle. The second section can extend, at least partially, in the interior flow direction.

[0038] An exemplary embodiment of the present disclosure provides a method of inhibiting formation of ground vortices for a nacelle, including directing a fluid, via a plurality of ports, from an exterior surface of the nacelle to an interior surface of the nacelle based at least in part on a pressure difference between the exterior surface and the interior.

[0039] In any of the embodiments disclosed herein, directing the fluid via the plurality of ports can include directing a fluid, at least partially, in an internal flow direction.

[0040] In any of the embodiments disclosed herein, the method can further include positioning one or more shields such that at least a section of the plurality of ports is blocked.

[0041] In any of the embodiments disclosed herein, the method can further include determining a flight phase; and shifting the one or more shields via a mechanical actuation based at least in part on the flight phase. The flight phase can be selected from a group consisting of taxi, takeoff, climb, cruise, descent, and landing.

[0042] These and other aspects of the present disclosure are described in the Detailed Description below and the accompanying drawings. Other aspects and features of embodiments will become apparent to those of ordinary skill in the art upon reviewing the following description of specific, exemplary embodiments in concert with the drawings. While features

of the present disclosure may be discussed relative to certain embodiments and figures, all embodiments of the present disclosure can include one or more of the features discussed herein. Further, while one or more embodiments may be discussed as having certain advantageous features, one or more of such features may also be used with the various embodiments discussed herein. In similar fashion, while exemplary embodiments may be discussed below as device, system, or method embodiments, it is to be understood that such exemplary embodiments can be implemented in various devices, systems, and methods of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043] The following detailed description of specific embodiments of the disclosure will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the disclosure, specific embodiments are shown in the drawings. It should be understood, however, that the disclosure is not limited to the precise arrangements and instrumentalities of the embodiments shown in the drawings.

[0044] FIG. 1 provides a nacelle including a plurality of ports, in accordance with some embodiments of the present disclosure.

[0045] FIG. 2 provides a forebody section of a nacelle including a plurality of ports, in accordance with some embodiments of the present disclosure.

[0046] FIGS. 3A and 3B provide zoomed-in cross-sectional views of a plurality of ports, in accordance with some embodiments of the present disclosure.

[0047] FIG. 4 provides a forebody section of a nacelle including a plurality of ports located in an azimuthal top two thirds portion, in accordance with some embodiments of the present disclosure.

[0048] FIG. 5 provides a reference for defining an azimuthal position of the plurality of ports, in accordance with some embodiments of the present disclosure.

[0049] FIGS. 6A-D provide embodiments of azimuthal locations for the plurality of ports, in accordance with some embodiments of the present disclosure.

[0050] FIGS. 7A and 7B provide embodiments of configurations of arrays of ports, in accordance with some embodiments of the present disclosure.

[0051] FIGS. 8A-C provide configurations of arrays of ports disposed on a forebody section of a nacelle, in accordance with some embodiments of the present disclosure.

[0052] FIG. 9 provides further configurations of arrays of ports disposed on a forebody section of a nacelle, in accordance with some embodiments of the present disclosure.

[0053] FIGS. 10A-E provide top and cross-sectional views of a section of ports including one or more shutters, in accordance with some embodiments of the present disclosure.

[0054] FIGS. 11A-F provide top and cross-sectional views of a section of ports including one or more shields, in accordance with some embodiments of the present disclosure.

[0055] FIG. 12 provides an example block diagram for a method of inhibiting formation of ground vortices based at least in part on a mechanical actuation, in accordance with some embodiments of the present disclosure.

DETAILED DESCRIPTION

[0056] To facilitate an understanding of the principles and features of the present disclosure, various illustrative embodiments are explained below. The components, steps, and materials described hereinafter as making up various elements of the embodiments disclosed herein are intended to be illustrative and not restrictive. Many suitable components, steps, and materials that would perform the same or similar functions as the components, steps, and materials described herein are intended to be embraced within the scope of the disclosure. Such other components, steps, and materials not described herein can include, but are not limited to, similar components or steps that are developed after development of the embodiments disclosed herein.

[0057] It should also be noted that, as used in the specification and the appended claims, the singular forms “a,” “an,” and “the” include plural references unless the context clearly dictates otherwise. References to a composition containing “a” constituent is intended to include other constituents in addition to the one named.

[0058] Also, in describing the disclosed technology, terminology will be resorted to for the sake of clarity. It is intended that each term contemplates its broadest meaning as understood by those skilled in the art and includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

[0059] Ranges may be expressed herein as from “about” or “approximately” or “substantially” one particular value and/or to “about” or “approximately” or “substantially” another particular value. When such a range is expressed, the disclosed technology can include from the one particular value and/or to the other particular value. Further, ranges described as being between

a first value and a second value are inclusive of the first and second values. Likewise, ranges described as being from a first value and to a second value are inclusive of the first and second values.

[0060] Herein, the use of terms such as “having,” “has,” “including,” or “includes” are open-ended and are intended to have the same meaning as terms such as “comprising” or “comprises” and not preclude the presence of other structure, material, or acts. Similarly, though the use of terms such as “can” or “may” are intended to be open-ended and to reflect that structure, material, or acts are not necessary, the failure to use such terms is not intended to reflect that structure, material, or acts are essential. To the extent that structure, material, or acts are presently considered to be essential, they are identified as such.

[0061] The components described hereinafter as making up various elements of the disclosed technology are intended to be illustrative and not restrictive. Many suitable components that would perform the same or similar functions as the components described herein are intended to be embraced within the scope of the disclosed technology. Such other components not described herein can include, but are not limited to, similar components that are developed after development of the presently disclosed subject matter.

[0062] Referring now to the drawings, in which like numerals represent like elements, the present disclosure is herein described. FIG. 1 illustrates a nacelle 100 including a plurality of ports 110. The nacelle 100 can include an exterior surface 102. As will be described in greater detail herein, the exterior surface 102 can have an associated exterior pressure, defined as a pressure outside the nacelle 100. The pressure outside the nacelle 100 can be a pressure of a fluid on the exterior surface 102. The exterior surface 102 can experience a plurality of forces. Specifically, the exterior surface 102 can experience side force components, as will be discussed in greater detail herein. For example, the side forces can be a crosswind. The nacelle 100 can further include an interior surface 104. In some embodiments, the exterior surface 102 can transition to the interior surface 104 at an inlet 108. The interior surface 104 can face radially inward within the nacelle 100. In some embodiments, the interior surface 104 can face an interior 106 of the nacelle 100. As will be appreciated, the nacelle 100 can be configured to receive a main fluid flow, such that the main fluid flow flows into the nacelle 100 through the inlet 108, and further into the interior 106 of the nacelle 100. That is, the inlet 108 can be configured to receive a fluid flow, or specifically the main fluid flow, into the interior 106 of the nacelle 100. After receiving the main fluid flow, the interior 106 can direct the main fluid

flow to the fan 120 of the nacelle. As will be discussed in greater detail herein, the plurality of ports 110 can be configured to direct a fluid flow at least partially towards the fan 120 of the nacelle 100. That is, the plurality of ports 110 can direct a fluid flow originating from the exterior surface 102 at least partially in a direction of the main fluid flow, which can be generally defined as from the inlet 108 to the fan 120. The main fluid flow can include an interior flow direction, defined as a direction of the main fluid flow within the interior 106. The main fluid flow can be characterized by having the interior flow direction from a first end to a second end of the nacelle 100. In some embodiments, the first end can be the inlet 108, and the second end can be the fan 120. In some embodiments, the second end can be any part of an engine of the nacelle 100 disposed downstream of the inlet 108. In some embodiments, the plurality of ports 110 can be disposed on a forebody section 150 of the nacelle 100. As will be appreciated, the forebody section 150 can include the inlet 108, the interior surface 104, and the exterior surface 102. In some embodiments, the plurality of ports 110 can be disposed on any longitudinal or azimuthal portion of the nacelle 100.

[0063] As will be discussed in greater detail herein, the plurality of ports 110 can extend from the exterior surface 102 to the interior surface 104. That is, a port of the plurality of ports 110 can include a through hole, such that a fluid can flow from the exterior surface 102, through the port, and to the interior surface 104. In some embodiments, the plurality of ports 110 can be configured to receive a fluid flow at the exterior surface 102. Further, the plurality of ports 110 can be configured to direct a fluid flow from the exterior surface 102 to the interior surface 104. That is, the plurality of ports 110 can be configured to direct a fluid from the exterior surface 102, through the plurality of ports, and to the interior 106, such that directing the fluid from the exterior surface 102 to the interior 106 can inhibit formation of ground vortices. As will be discussed in greater detail herein, inhibiting the formation of ground vortices can have beneficial effects on engine and aircraft performance. The plurality of ports 110 can be further configured to expel a fluid flow at the interior surface 104. In this way, as will be appreciated, the plurality of ports 110 can be configured to transfer a fluid which comes into contact with the exterior surface 102 from the exterior surface 102 to the interior 106 via one or more through holes extending from the exterior surface 102 to the interior surface 104.

[0064] FIG. 2 illustrates the forebody section 150, as discussed herein, separate from the nacelle 100. As discussed herein, the forebody section 150 can include the inlet 108, such that the plurality of ports 110 can be located proximal, or near, to the inlet 108, as shown in FIGs.

1-2. In this way, a fluid flow directed through the plurality of ports 110 can join the main fluid flow received by the inlet 108 before the main fluid flow enters the fan 120 of the nacelle 100. As will be discussed in greater detail herein, the plurality of ports 110 can be disposed on any azimuthal portion of the forebody section 150. As shown in FIG. 2, the plurality of ports 110 can be distributed about an entire azimuthal portion, or as will be appreciated, a 360 degree azimuthal portion. The plurality of ports 110, as will be discussed in greater detail herein, can be arranged in an array of ports, such that the array of ports can be characterized by distinct rows and columns of ports. The array of ports can be further defined by a porosity. That is, the porosity, as is understood by those skilled in the art, can define the separation between rows and columns of ports of the array of ports. The porosity can be within any range of the following values: 3%, 4%, 5%, 6%, 48%, 49%, 50%, 51%, and 52%. Specifically, the array of ports can have the porosity between approximately 3% and approximately 52%.

[0065] FIGS. 3A and 3B illustrates zoomed-in cross-sectional views of example embodiments of a nacelle including a plurality of ports. As shown in FIG. 3A, the plurality of ports 110 can include a port 310, which can extend from the exterior surface 102 to the interior surface 104. That is, the port 310 can extend through a nacelle from the exterior surface 102 to the interior surface 104. As is shown, the port 310 can comprise a plurality of through holes. The port 310 can define an internal flow path, such that the internal flow path can be configured to alter a direction of a fluid flow through the port 310. That is, the port 310 can include a first section 312 and a second section 314. The first section 312 can be located proximal to the exterior surface 102. Similarly, the second section 314 can be located proximal to the interior surface 104. The first section 312 and the second section 314 can extend in substantially different directions. In some embodiments, the first section 312 can extend substantially radially towards a centerline of the nacelle. That is, the first section 312 can extend substantially orthogonally to the interior flow direction of the main fluid flow. More specifically, the first section 312 can extend substantially orthogonally to an opening of the port 310 disposed on the exterior surface 102. In some embodiments, as illustrated in FIG. 3A, the first section 312 can extend at least partially opposite the interior flow direction. In this way, the port 310 of the plurality of ports 110 can be configured to pass fluid travelling in the interior flow direction on the exterior surface 102 so as to limit drag incurred by the plurality of ports 110. The second section 314 can extend substantially radially towards a centerline of the nacelle 100. That is, the second section 314 can extend substantially orthogonally to the interior flow direction of the main fluid

flow. The second section 314, as will be discussed in greater detail herein, can extend at least partially in the interior flow direction. In this way, the second section 314 can be configured to direct a fluid flow at least partially in the interior flow direction. Moreover, the second section 314 can be configured to expel a fluid at least partially into the interior flow direction into the interior 106, so as to mitigate any turbulence in mixing separate flows, such as mixing the fluid flow transferred via the plurality of ports 110 with the main fluid flow within the interior 106. Further, the port 310 can be a passive port, such that a passive port can be defined as being configured to direct a fluid from the exterior surface 102 to the interior surface 104 due to a pressure difference of the exterior surface 102 and the interior surface 104. Any port of the plurality of ports 110 may be a passive port.

[0066] FIG. 3B illustrates a port 320 of the plurality of ports 110. The port 320 can include any embodiments described herein for the port 310. Additionally, the port 320 may include additional embodiments which may contribute to exemplary performance of the plurality of ports 110. Such embodiments may include the port 320 including a first section 322 and a second section 324. The first section 322 may include any embodiments described herein for the first section 312. Additionally, the first section 322 may further include a straight portion and a curved portion, such that the straight portion is proximal to the exterior surface 102. The curved portion may be configured to be a transition between the first section 322 and the second section 324, or a bend transitioning between different flow directions of the first section 322 and the second section 324. In this way, the curved portion can be implemented to mitigate turbulent flow caused by sharp corners in fluid flow chambers or ports. The second section 324 can include any embodiments of the second section 314 as discussed herein. Additionally, the second section 324 can extend partially in the interior flow direction, as shown in FIG. 3B. In this way, the second section 324 can direct the fluid flow through the plurality of ports 110 at least partially in the interior flow direction. The fluid flow through the first section 322 and the second section 324 can be driven by the pressure difference between the exterior surface 102 and the interior surface 104.

[0067] FIG. 4 illustrates a forebody section 400 including a plurality of ports 410. The nacelle 100 can include the forebody section 400. The forebody section 400, as will be appreciated, can include the exterior surface 102, the interior surface 104, and the interior 106. The nacelle 100 including the forebody section 400 can further include a top portion and a bottom portion. As will be discussed in greater detail herein, the bottom portion can be in proximity to a ground

plane, and the top portion can be opposing the bottom portion. Azimuthal ranges for the top and bottom portions will be discussed in greater detail herein. Accordingly, the plurality of ports 410 can be located in the top portion of the nacelle 100. As is shown in FIG. 4, the forebody section 400 can include the top and bottom portions of the nacelle 100. For example, the plurality of ports 410 can be disposed on the top portion of the forebody section 400. Specifically, the plurality of ports 410 can span the top portion. The plurality of ports 410, as discussed herein, can be in the form of an array of ports azimuthally spanning the top portion. The top portion can be defined as an azimuthal top two thirds portion, as will be discussed in greater detail herein.

[0068] FIG. 5 illustrates a reference 500 for defining the top and bottom portions of the nacelle 100. In some embodiments, the reference 500 can include a reference mark 502. The reference mark 502 can be located at a top end of the nacelle 100, or at a farthest azimuthal point from the ground plane. The reference mark 502 can also be defined as 0 degrees. The reference 500 can further include a potentially infinite number of markings to define an azimuthal position about the nacelle 100 with respect to the reference mark 502. For example, a mark 504 can be located at 90 degrees, a mark 506 can be located at 180 degrees, a mark 508 can be located at 210 degrees, a mark 510 can be located at 240 degrees, a mark 512 can be located at 270 degrees, a mark 514 can be located at 300 degrees, a mark 516 can be located at 330 degrees, etc. In this way, the azimuthal top two thirds portion can be defined as the top portion spanning from the mark 510 (at 240 degrees) to a 120 degree mark, including the reference mark 502. Furthermore, in embodiments where the top portion is the azimuthal top two thirds portion, the bottom portion can be a bottom third portion, spanning from the 120 degree mark to the mark 510 (at 240 degrees), including the mark 506 (at 180 degrees). The top portion, accordingly, can be a top half portion, a top three quarter portion, a top third portion, similarly defined to the azimuthal top two thirds portion.

[0069] FIGS. 6A-D illustrate embodiments of azimuthal distributions of a plurality of ports on a nacelle. As shown in FIG. 6A, the plurality of ports can be located in an azimuthal portion 610. As shown in FIG. 6B, the plurality of ports can be located in an azimuthal portion 620. As shown in FIG. 6C, the plurality of ports can be located in an azimuthal portion 630. As shown in FIG. 6D, the plurality of ports can be located in an azimuthal portion 640.

[0070] FIGS. 7A and 7B illustrate embodiments of arrays of ports. As discussed herein, the plurality of ports 110 can be in the form of an array of ports. The array of ports can be

characterized by an array pattern, or configuration. The array pattern, as shown in FIG. 7A, can include a pattern 710, such that a number of ports per row of the array increases steadily then decreases steadily. The array pattern, as shown in FIG. 7B, can include a pattern 720. In some embodiments, the array pattern can be characterized as being symmetrical. In some embodiments, the array of ports comprises a plurality of sections, each section having a pattern. Each section of the plurality of sections, in some embodiments, can have the same array pattern. In some embodiments, at least one section of the plurality of sections differs in pattern from at least one other section of the plurality of sections. As will be appreciated, the plurality of sections can be distributed about a portion of the nacelle occupied by the plurality of ports, such that each section of the plurality of sections is separated from another section by a gap lacking ports.

[0071] FIGS. 8A-C illustrate embodiments of arrays of ports disposed on a forebody section of the nacelle 100. The array of ports can include a pattern 810, such that ports of the pattern 810 are evenly distributed about an azimuthal portion of the forebody section. The pattern 810 can be further characterized by having a same number of ports in each row of ports. The array of ports, as shown in FIG. 8B, can include a pattern 820. The pattern 820 is similar to the pattern 810, and the pattern 820 can be characterized as having a larger gap in between rows of the array of ports. The array of ports can include a pattern 830. Similar to the discussion of the array pattern of FIG. 7A, the pattern 830 can include a variable number of ports in each row of the array of ports. Likewise, the variable number of ports can be symmetrical, patterned, or optimized based at least in part on azimuthal position. The azimuthal portion which the pattern 810, the pattern 820, or the pattern 830 spans can be any azimuthal portion discussed herein.

[0072] FIG. 9 illustrates further patterns of arrays of ports on the nacelle 100. As discussed herein, patterns of the arrays of ports can be disposed upon a forebody section of the nacelle 100, as is shown in FIG. 9, may also be disposed on any azimuthal portion of the nacelle 100. The array of ports can include a pattern 910, a pattern 920, a pattern 930, a pattern 940, a pattern 950, a pattern 960, a pattern 970, or a pattern 980. The array of ports may include any combination of any pattern of ports discussed or illustrated herein. As will be discussed in greater detail herein, one or more ports or sections of ports may be blocked in such a fashion that the plurality of ports 110, as shown in FIG. 1, has an effective pattern including any of the patterns discussed herein.

[0073] FIGS. 10A-E illustrate active embodiments for blocking one or more ports of the plurality of ports 110. The nacelle 100 can further include one or more shields, such that the one or more shields can be configured to block fluid flow through one or more ports of the plurality of ports 110. In some embodiments the one or more shields can be configured to block fluid flow through at least a portion of ports of the plurality of ports 110. In the active embodiments illustrated in FIGS. 10A-E, the one or more shields can be one or more shutters. For example, as shown in FIG. 10A, the plurality of ports 110 can include a section of ports 1000, such that the section of ports 1000 includes a port 1002. The section of ports 1000 can be characterized by being open, such that fluid can flow through the section of ports 1000 as discussed herein for the plurality of ports 110.

[0074] FIG. 10B illustrates a cross-sectional view of the section of ports 1000. As shown in FIG. 10B, the section of ports 1000 can include the exterior surface 102 and the interior surface 104. As shown in FIG. 10C, the plurality of ports 110 can further include a section of ports 1010. The section of ports 110 can include one or more shutters, such that the one or more shutters can be configured to block fluid flow through one or more ports of the section of ports 1010. The one or more shutters can be mechanisms similar to a camera shutter as known in the art, and as shown. The section of ports 1010 can include a port 1012, such that fluid can flow through the port 1012 as discussed herein. As will be appreciated, the section of ports 1010 can further include a port 1014, such that the port 1014 is figured to be at least partially blocked via a shutter. The section of ports 1010 can further include a port 1016, such that the port 1016 is configured to be at least partially blocked via a shutter, and may have a smaller effective aperture for fluid to flow through than the port 1014. The section of ports 1010 can further include a closed port 1018, such that fluid is blocked from flowing through the closed port 1018. In this way, the plurality of ports 110 can include any number or combination of the section of ports 1000 and the section of ports 1010. In some embodiments, the section of ports 1010 is part of a plurality of sections of ports, including a plurality of each of the port 1014, the port 1016, and the port 1018. As can be appreciated, the port 1014, the port 1016, and the port 1018 can be representative of a process of closing any port of the plurality of ports 110 or any port of the section of ports 1010, in that any port located in any location of port discussed herein may be configured to be at least partially closed in the form of the port 1014, the port 1016, or the port 1018. As shown in FIG. 10D, one or more shutters 1020 can be located on the interior surface 104 of the nacelle 100. That is, the one or more shutters 1020 can be at least

partially disposed within the interior surface 104. As shown in FIG. 10E, the one or more shutters 1020 can be located on the exterior surface 102. That is, the one or more shutters 1020 can be at least partially disposed within the exterior surface 102. In some embodiments, the one or more shutters 1020 can be located on both the interior surface 104 and the exterior surface 102.

[0075] FIGS. 11A-E illustrate additional active embodiments of blocking one or more ports of the plurality of ports 110. As shown in FIG. 11A, the plurality of ports 110 can include a section of ports 1100 characterized by each port being blocked. The section of ports 1100 can be further characterized by having one or more shields configured to block each port of the section of ports 1100. That is, the one or more shields may include a plurality of apertures configured to align with at least a section of ports. Furthermore, the section of ports 1100 can be characterized by having a configuration such that the plurality of apertures of the one or more shields is aligned with the section of ports 1100 such that each port of the section of ports 1100 is blocked. That is, the section of ports 1100 can have a closed configuration, in which the one or more shields are positioned to block fluid flow through each port of the plurality of ports 110. In some embodiments, dotted circles illustrated in FIGS. 11A and 11C represent openings of ports of the plurality of ports 110, and solid circles represent apertures of the plurality of apertures of the one or more shields. A cross-sectional view of the section of ports 1100 is illustrated in FIG. 11B. The one or more shields, as discussed herein, can include a shield 1106 further including an aperture 1104 of the plurality of apertures. The section of ports 1100 can include a port 1102, being representative of any port of the plurality of ports 110 discussed herein. The port 1102, in the closed configuration of the section of ports 1100, can be blocked from receiving a fluid flow from at least one of the interior surface 104 and the exterior surface 102. That is, the one or more shields can be located on at least one of the interior surface 104 and the exterior surface 102 of the nacelle 100. In some embodiments, the one or more shields may be disposed within at least one of the interior surface 104 and the exterior surface 102.

[0076] As shown in FIG. 11C, the plurality of ports 110 can include a section of ports 1110. The section of ports 1110 can be characterized as being in a partially open configuration, in which the one or more shields are positioned to block fluid flow through at least a portion of ports of the plurality of ports 110. That is, the partially open configuration may include embodiments where the one or more shields can partially block each port of at least the section of ports 1110. The partially open configuration of the section of ports 1110 illustrated in FIG.

11C can also be representative of a transition between an open and a closed section of ports. As will be discussed in greater detail herein, the transition between the open configuration and a closed configuration may be due to an azimuthal shift of the one or more shields. A cross-sectional view of the section of ports 1110 characterized by the partially open configuration is illustrated in FIG. 11D. As is shown, the shield 1106 including the aperture 1104 can be positioned such that at least a portion of the port 1102 of the section of ports 1110 is blocked.

[0077] As shown in FIG. 11E, the plurality of ports 110 can include a section of ports 1120 characterized by being in an open configuration, in which the one or more shields are positioned such that fluid may flow through each port of the plurality of ports 110. The open configuration can be further characterized by an alignment of the one or more shields and one or more corresponding ports of the section of ports 1120, such that the plurality of apertures of the one or more shields align with ports of the section of ports 1120. As shown in FIG. 11F, the aperture 1104 can align with the port 1102 such that a fluid can flow through the port 1102. The shield 1106 can be disposed in between ports of the section of ports 1120 when the section of ports 1120 is in the open configuration.

[0078] The one or more shields, in any of the active embodiments described herein, may be configured to block a flow of the fluid due to a mechanical actuation. The mechanical actuation can be characterized by being at least partially mechanical, that is, the mechanical actuation may further include electrical components, processors, computers, computer readable mediums, machine learning algorithms, and corresponding user interfaces. The mechanical actuation, in the case of the one or more shutters 1020 illustrated in FIGS. 10A-E, may include an opening and a closing of a shutter of the one or more shutters 1020. The opening and the closing of the one or more shutters may include transitioning from one embodiment of port to another embodiment of port as shown in FIG. 10C, including but not limited to the port 1014, the port 1016, and the port 1018. The mechanical actuation, in the case of the one or more shields including the shield 1106 illustrated in at least FIG. 11B, can include an azimuthal shift of the one or more shields. As will be appreciated, as the one or more shields transition between the open configuration, the partially open configuration, and the closed configuration, due to the surface of the nacelle 100 being rounded, for the one or more shields to shift during transition, the one or more shields can shift azimuthally about the nacelle 100. That is, the one or more shields can be configured such that the mechanical actuation causes the one or more shields to transition among one or more configurations selected from a group consisting of: the

open configuration, the partially open configuration, and the closed configuration. In this way, an azimuthal alignment, altered by the azimuthal shift, of the one or more shields can be configured to alter flow of a fluid through at least a portion of ports of the plurality of ports 110, so as to inhibit formation of ground vortices about the nacelle 100.

[0079] As can be appreciated, the mechanical actuation can be prompted by a user input. In this way, an operator, or the user, can adjust the one or more shields, and thus the alignment of the one or more shields, via the mechanical actuation. The mechanical actuation, in the case of user input, can be based at least in part on a flight phase. For example, a desired alignment of the one or more shields may change depending on the flight phase of the aircraft. The flight phase can be selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing. As can be appreciated, additional, more specific flight phases can be considered as understood in the art. Specifically, a desired configuration of the one or more shields can be selected based at least in part on the flight phase. The desired configuration can be based at least in part on one or more flight factors, as will be discussed in greater detail herein. The desired configuration can be selected based at least in part on a need to inhibit formation of ground vortices. The need to inhibit the formation of ground vortices is discussed in greater detail herein. As is understood by those skilled in the art, there are many potential situations in flight, for example, with wind patterns, which may prompt the user input, or mechanical actuation, within one of the flight phases discussed herein. In this way, the mechanical actuation of the one or more shields is not constrained to a transition between the flight phases. Moreover, the transition between the flight phases may include an autonomous trigger of the mechanical actuation, in that the transition between the flight phases may be characterized by a baseline number or section of ports being blocked.

[0080] As discussed herein, the mechanical actuation may be autonomously triggered. That is, the mechanical actuation may be autonomously triggered based at least in part on one or more flight factors. The one or more flight factors may be characterized as factors independent of the flight phase. In this way, the one or more flight factors may be considered to be in constant flux, or a constant state of change through the duration of a flight phase. For example, the one or more flight factors can include wind direction, wind speed, air pressure change, engine efficiency, internal-external nacelle pressure difference, aircraft speed, flight duration, flight altitude, engine fan speed, engine thrust, or any combination thereof. Autonomous triggering may include a PID control element. The mechanical actuation can be autonomously triggered

based at least in part on a machine learning model, such that the mechanical actuation can be triggered based at least in part on past data for the one or more flight factors. In some embodiments, the machine learning model can be a convolutional neural network.

[0081] FIG. 12 illustrates a block diagram of an example method of inhibiting formation of ground vortices for a nacelle. The method can include determining 1210 a flight phase. The method can further include shifting 1220 shields via a mechanical actuation. The method can further include positioning 1230 the shields such that at least a section of ports is blocked. The method can further include directing 1240 fluid from an exterior surface of the nacelle to an interior surface of the nacelle.

[0082] Directing 1240 the fluid from an exterior surface of the nacelle to the interior surface of the nacelle can include directing the fluid, via a plurality of ports, from the exterior surface of the nacelle to the interior surface of the nacelle based at least in part on a pressure difference between the exterior surface and the interior surface. Directing the fluid via the plurality of ports can include directing the fluid, at least partially, in an internal flow direction. The flight phase may be selected from a group consisting of taxi, takeoff, climb, cruise, descent, and landing.

[0083] Examples

[0084] The following sections illustrate example implementations of the present disclosure.

[0085] Distributed Bleed Control

[0086] An objective of the present disclosure is to demonstrate the efficacy of active flow control (AFC) at the nacelle inlet that leads to the ingestion of flow around the nacelle's periphery to control and suppress the formation of the ground vortex by changing the external flow field. This control method can be adjustable so that it can be continuously and adaptively optimized for a range of operating stages throughout the flight envelope to help to overcome other adverse inlet flow effects such as those encountered by crosswind and enable for the optimization of the effectiveness of the inlet for different flow speeds including cruise.

[0087] In the present disclosure, the actuation can be provided by a novel approach to aerodynamic control using distributed, scalable autonomous air bleed actuation on a conventional nacelle inlet. This approach builds on earlier investigations at Georgia Tech in which this AFC technology was successfully applied for controlling inlet flow separation on the internal surface of the inlet. The bleed can be driven through the nacelle's aerodynamic surfaces by the inherent pressure differences between the inner and outer surfaces when the

engine is operating. The bleed can be autonomous or regulated by low-power, surface-integrated louver valves (e.g., piezoelectric). The interaction between controlled bleed and the cross flow can be tailored to leverage the generation and regulation of vorticity concentrations on or near the surface to locally alter its apparent aerodynamic shape and therefore the flow direction and aerodynamic loads. Bleed actuation which is driven solely by local pressure differences across the airframe, does not require powered air source, is easily airframe integrable and scalable in low-observable fashion, and can be used to mitigate separation in complex wind gusts during taxiing, takeoff, and landing. The notional bleed ports can cover any part of the circumference of the nacelle inlet and the valves can be implemented at one or both ends to dynamically change the open ports on the inlet surface.

[0088] Implementation of Distributed Aerodynamic Bleed in Nacelle Inlets

[0089] The effectiveness of bleed actuation on the flow around a (nominally 6%-scale) nacelle inlet model has been demonstrated in the presence of relevant crosswind conditions in laboratory experiments at Georgia Tech using a controlled blower operated in suction as a surrogate model of the engine plant and a wind tunnel to simulate the crosswind effect. These investigations have shown that, when in close proximity to a ground plane, a ground vortex may form when the inlet speed surpasses some critical value. The effectiveness of passive autonomous bleed configurations (i.e., without using control valves for regulation of the bleed flow) was demonstrated using multiple configurations. The flow conditions that lead to the onset of a ground vortex that is ingested into the nacelle can depend on three formation parameters namely, the inlet mass flow rate, crosswind speed, and distance between the nacelle and ground plane. It was shown that these parameters can be combined into two dimensionless groups: the ratio of the inlet to cross stream momentum fluxes at which the vortex first forms, $\dot{P}_o^* = (\dot{m}V/\rho U_o^2 D^2)_o$, and the ratio of the inlet plane diameter to nacelle height above the ground plane, D/h . Together, these two parameters can be used to mark the boundary beyond which ground vortices are formed within the flow as depicted in a formation map. Any conditions above each curve will form a vortex for that particular inlet configuration proving that, with the partially opened nacelle, the inlet thrust can be increased to over 300% that of the baseflow before a vortex will ultimately form.

[0090] The reason that this control is effective is because of its impact on the external flow field. The ground vortex forms because of the initiation of reversed flow from underneath the inlet. When the peripheral bleed is placed around the inlet surface, it gives the inlet more area

to draw air from which decreases the overall velocity at every location. This prevents or delays the inlet from pulling air near the ground which delays the wrap up of vortices in the shear layer and prevents the ground vortex formation and ingestion. The case where the bottom holes are disabled performs better than the fully open inlet as this further prevents the ingestion of air from along the ground and continues to delay this airflow from initially creating vortices. Considering one case that forms a ground vortex for the solid inlet but not the others, pathlines can be created using the three-dimensional velocity field. The vortex is apparent in the base flow. For the control cases, there is significantly less air being drawn from underneath the inlet which prevents the vortex from forming.

[0091] Not only does this control method delay the onset of the vortex formation, but it also reduces the overall distortion, a measure of the heterogeneity of the flow, that is measured at the location of the fan face compared to a case that experiences windward side internal flow separation. These two control configurations were chosen to target the formation of the ground vortex, but the configurations can be optimized to prevent the separation alone if the conditions are not such that a ground vortex will form. The distortion in the absence of separation presents the limit case. When the flow separates in a crosswind, the distortion follows a standard offset regardless of the crosswind speed. The peripheral bleed configurations introduce more distortion than in the absence of separation, but they are each able to enhance the distortion compared to the separated baseflow. If optimized for the conditions, this performance could be further improved.

[0092] Several numerical studies investigated suppression of the ground vortex using external air jets on the nacelle including fan reverser jets (Johns, 2002; Shmilovich & Yadlin, 2006) and pulsed jets (Johns, 2002; Shmilovich & Yadlin, 2011). Notably, the simulations of Shmilovich & Yadlin (2006, 2011) indicated that ground vortex ingestion could be prevented by using ‘sprinkler’ jet actuation. These previously proposed methods for preventing the vortex rely on a compressed air source to blow the vortex away which requires the use of a compressor and can potentially introduce previously undisturbed particles into the inlet’s capture area.

[0093] In summary, the new active flow control methodology by using distributed peripheral aerodynamic bleed has the potential to pave the way for integrated control of nacelle inlet flow in propulsion systems. The bleed actuation which is driven by the inherent pressure difference across the nacelle inlet surfaces can help mitigate the unsteady inlet effects in propulsion systems both in takeoff and landing (e.g., ground vortex, separation bubble, unsteady crosswind) and during

flight (rapid climb or descent). In addition to delaying the formation of the ground vortex for a given engine pressure ratio (EPR), active bleed control can also mitigate inlet distortion and interactions with the compressor blades which can cause blade damage and compressor stall.

[0094] The disclosed technology can be further understood according to the following clauses:

[0095] Clause 1: A nacelle comprising: an exterior surface; an interior surface; an interior; and a plurality of ports, extending through the nacelle from the exterior surface to the interior surface, wherein the plurality of ports is configured to direct a fluid from the exterior surface to the interior, such that directing the fluid from the exterior surface to the interior inhibits formation of ground vortices.

[0096] Clause 2: The nacelle of Clause 1, wherein the plurality of ports is configured to direct the fluid from the exterior surface to the interior based at least in part on a pressure difference of the fluid between the exterior surface and the interior surface.

[0097] Clause 3: The nacelle of Clause 1, wherein the plurality of ports is an array of ports with a porosity between approximately 5% and approximately 50%.

[0098] Clause 4: The nacelle of Clause 1, further comprising: a bottom portion in proximity to a ground plane; and a top portion opposing the bottom portion, wherein at least a portion of the plurality of ports is located in the top portion.

[0099] Clause 5: The nacelle of Clause 4, wherein the top portion is defined as an azimuthal top two thirds portion of the nacelle.

[00100] Clause 6: The nacelle of Clause 5, wherein the plurality of ports is in the form of an array of ports azimuthally spanning the top portion.

[00101] Clause 7: The nacelle of Clause 1, wherein at least one port of the plurality of ports is a passive port.

[00102] Clause 8: The nacelle of Clause 1, further comprising one or more shields, wherein the one or more shields are configured to block fluid flow through at least a portion of ports of the plurality of ports.

[00103] Clause 9: The nacelle of Clause 8, wherein the one or more shields are located on one of the interior surface and the exterior surface of the nacelle.

[00104] Clause 10: The nacelle of Clause 8, wherein the one or more shields are configured to block a flow of the fluid due to a mechanical actuation.

[00105] Clause 11: The nacelle of Clause 10, wherein the mechanical actuation comprises an azimuthal shift of the one or more shields.

[00106] Clause 12: The nacelle of Clause 10, wherein the mechanical actuation is prompted by a user input.

[00107] Clause 13: The nacelle of Clause 10, wherein the mechanical actuation is autonomously triggered based at least in part on one or more flight factors, the one or more flight factors including wind direction, wind speed, air pressure change, engine efficiency, internal-external nacelle pressure difference, aircraft speed, flight duration, flight altitude, engine fan speed, engine thrust, or any combination thereof.

[00108] Clause 14: The nacelle of Clause 10, wherein the mechanical actuation is based at least in part on a flight phase, wherein the flight phase is selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

[00109] Clause 15: The nacelle of Clause 10, wherein the one or more shields are configured such that the mechanical actuation causes the one or more shields to transition among one or more configurations selected from a group consisting of: an open configuration, in which the one or more shields are positioned such that fluid may flow through each port of the plurality of ports, a partially open configuration, in which the one or more shields are positioned to block fluid flow through at least a portion of ports of the plurality of ports, and a closed configuration, in which the one or more shields are positioned to block fluid flow through each port of the plurality of ports.

[00110] Clause 16: The nacelle of Clause 15, wherein a desired configuration of the one or more shields is selected based at least in part on a flight phase, wherein the flight phase is selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

[00111] Clause 17: The nacelle of Clause 1, wherein the nacelle further comprises an inlet, wherein the inlet is configured to receive a main fluid flow, wherein the main fluid flow is characterized by having an interior flow direction from a first end to a second end of the nacelle, and wherein the plurality of ports is configured to direct the fluid, at least partially, in the interior flow direction.

[00112] Clause 18: The nacelle of Clause 17, wherein the plurality of ports extends, at least partially, in the interior flow direction.

[00113] Clause 19: The nacelle of Clause 17, wherein at least one port of the plurality of ports comprises: a first section proximal to the exterior surface; and a second section proximal to the interior surface, wherein the first section extends substantially radially towards a centerline of the nacelle, wherein the second section extends, at least partially, in the interior flow direction.

[00114] Clause 20: A nacelle comprising: an exterior surface; an interior surface; an interior; and a plurality of ports, comprising an array of ports distributed azimuthally about at least a portion of the nacelle, wherein the array of ports spans a top portion of the nacelle, wherein when a fluid comes into contact with the exterior surface, the plurality of ports is configured to direct the fluid from the exterior surface to the interior of the nacelle.

[00115] Clause 21: The nacelle of Clause 20, further comprising one or more shields, wherein the one or more shields are configured to block fluid flow through at least a portion of ports of the plurality of ports.

[00116] Clause 22: The nacelle of Clause 21, wherein the one or more shields are located on one of the interior surface and the exterior surface of the nacelle.

[00117] Clause 23: The nacelle of Clause 21, wherein the one or more shields are configured to block a flow of the fluid due to a mechanical actuation.

[00118] Clause 24: The nacelle of Clause 23, wherein the mechanical actuation comprises an azimuthal shift of the one or more shields.

[00119] Clause 25: The nacelle of Clause 23, wherein the mechanical actuation is prompted by a user input.

[00120] Clause 26: The nacelle of Clause 23, wherein the mechanical actuation is autonomously triggered based at least in part on one or more flight factors, the one or more flight factors including wind direction, wind speed, air pressure change, engine efficiency, internal-external nacelle pressure difference, aircraft speed, flight duration, flight altitude, engine fan speed, engine thrust, or any combination thereof.

[00121] Clause 27: The nacelle of Clause 23, wherein the mechanical actuation is based at least in part on a flight phase, wherein the flight phase is selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

[00122] Clause 28: The nacelle of Clause 23, wherein the one or more shields are configured such that the mechanical actuation causes the one or more shields to transition among one or more configurations selected from a group consisting of: an open configuration, in which the one or more shields are positioned such that fluid may flow through each port of the plurality of ports, a partially open configuration, in which the one or more shields are positioned to block fluid flow through at least a portion of ports of the plurality of ports, and a closed configuration, in which the one or more shields are positioned to block fluid flow through each port of the plurality of ports.

[00123] Clause 29: The nacelle of Clause 28, wherein a desired configuration of the one or more shields is selected based at least in part on a flight phase, wherein the flight phase is selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

[00124] Clause 30: The nacelle of Clause 20, wherein the nacelle further comprises an inlet, wherein the inlet is configured to receive a main fluid flow, wherein the main fluid flow is characterized by having an interior flow direction from a first end to a second end of the nacelle, and wherein the plurality of ports is configured to direct the fluid, at least partially, in the interior flow direction.

[00125] Clause 31: The nacelle of Clause 30, wherein at least one port of the plurality of ports extends, at least partially, in the interior flow direction.

[00126] Clause 32: The nacelle of Clause 30, wherein at least one port of the plurality of ports comprises: a first section proximal to the exterior surface; and a second section proximal to the interior surface, wherein the first section extends substantially radially to a centerline of the nacelle, wherein the second section extends, at least partially, in the interior flow direction.

[00127] Clause 33: A method of inhibiting formation of ground vortices for a nacelle, comprising: directing a fluid, via a plurality of ports, from an exterior surface of the nacelle to an interior of the nacelle based at least in part on a pressure difference between the exterior surface and the interior.

[00128] Clause 34: The method of Clause 33, wherein directing the fluid via the plurality of ports comprises directing a fluid, at least partially, in an internal flow direction.

[00129] Clause 35: The method of Clause 33, further comprising positioning one or more shields such that at least a section of the plurality of ports is blocked.

[00130] Clause 36: The method of Clause 35, further comprising: determining a flight phase, the flight phase being selected from a group consisting of taxi, takeoff, climb, cruise, descent, and landing; and shifting the one or more shields via a mechanical actuation based at least in part on the flight phase.

[00131] It is to be understood that the embodiments and claims disclosed herein are not limited in their application to the details of construction and arrangement of the components set forth in the description and illustrated in the drawings. Rather, the description and the drawings provide examples of the embodiments envisioned. The embodiments and claims disclosed herein are further capable of other embodiments and of being practiced and carried out in

various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purposes of description and should not be regarded as limiting the claims.

[00132] Accordingly, those skilled in the art will appreciate that the conception upon which the application and claims are based may be readily utilized as a basis for the design of other structures, methods, and systems for carrying out the several purposes of the embodiments and claims presented in this application. It is important, therefore, that the claims be regarded as including such equivalent constructions.

[00133] Furthermore, the purpose of the foregoing Abstract is to enable the United States Patent and Trademark Office and the public generally, and especially including the practitioners in the art who are not familiar with patent and legal terms or phraseology, to determine quickly from a cursory inspection the nature and essence of the technical disclosure of the application. The Abstract is neither intended to define the claims of the application, nor is it intended to be limiting to the scope of the claims in any way.

CLAIMS

What is claimed is:

1. A nacelle comprising:
 - an exterior surface;
 - an interior surface;
 - an interior; and
 - a plurality of ports, extending through the nacelle from the exterior surface to the interior surface,wherein the plurality of ports is configured to direct a fluid from the exterior surface to the interior, such that directing the fluid from the exterior surface to the interior inhibits formation of ground vortices.
2. The nacelle of Claim 1, wherein the plurality of ports is configured to direct the fluid from the exterior surface to the interior based at least in part on a pressure difference of the fluid between the exterior surface and the interior surface.
3. The nacelle of Claim 1, wherein the plurality of ports is an array of ports with a porosity between approximately 5% and approximately 50%.
4. The nacelle of Claim 1, further comprising:
 - a bottom portion in proximity to a ground plane; and
 - a top portion opposing the bottom portion, wherein at least a portion of the plurality of ports is located in the top portion.
5. The nacelle of Claim 4, wherein the top portion is defined as an azimuthal top two thirds portion of the nacelle.
6. The nacelle of Claim 5, wherein the plurality of ports is in the form of an array of ports azimuthally spanning the top portion.
7. The nacelle of Claim 1, wherein at least one port of the plurality of ports is a passive port.

8. The nacelle of Claim 1, further comprising one or more shields, wherein the one or more shields are configured to block fluid flow through at least a portion of ports of the plurality of ports.

9. The nacelle of Claim 8, wherein the one or more shields are located on one of the interior surface and the exterior surface of the nacelle.

10. The nacelle of Claim 8, wherein the one or more shields are configured to block a flow of the fluid due to a mechanical actuation.

11. The nacelle of Claim 10, wherein the mechanical actuation comprises an azimuthal shift of the one or more shields.

12. The nacelle of Claim 10, wherein the mechanical actuation is prompted by a user input.

13. The nacelle of Claim 10, wherein the mechanical actuation is autonomously triggered based at least in part on one or more flight factors, the one or more flight factors including wind direction, wind speed, air pressure change, engine efficiency, internal-external nacelle pressure difference, aircraft speed, flight duration, flight altitude, engine fan speed, engine thrust, or any combination thereof.

14. The nacelle of Claim 10, wherein the mechanical actuation is based at least in part on a flight phase, wherein the flight phase is selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

15. The nacelle of Claim 10, wherein the one or more shields are configured such that the mechanical actuation causes the one or more shields to transition among one or more configurations selected from a group consisting of:

an open configuration, in which the one or more shields are positioned such that fluid may flow through each port of the plurality of ports,

a partially open configuration, in which the one or more shields are positioned to block fluid flow through at least a portion of ports of the plurality of ports, and

a closed configuration, in which the one or more shields are positioned to block fluid flow through each port of the plurality of ports.

16. The nacelle of Claim 15, wherein a desired configuration of the one or more shields is selected based at least in part on a flight phase, wherein the flight phase is selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

17. The nacelle of Claim 1, wherein the nacelle further comprises an inlet, wherein the inlet is configured to receive a main fluid flow, wherein the main fluid flow is characterized by having an interior flow direction from a first end to a second end of the nacelle, and wherein the plurality of ports is configured to direct the fluid, at least partially, in the interior flow direction.

18. The nacelle of Claim 17, wherein the plurality of ports extends, at least partially, in the interior flow direction.

19. The nacelle of Claim 17, wherein at least one port of the plurality of ports comprises:
a first section proximal to the exterior surface; and
a second section proximal to the interior surface,
wherein the first section extends substantially radially towards a centerline of the nacelle,
wherein the second section extends, at least partially, in the interior flow direction.

20. A nacelle comprising:
an exterior surface;
an interior surface;
an interior; and
a plurality of ports, comprising an array of ports distributed azimuthally about at least a portion of the nacelle,
wherein the array of ports spans a top portion of the nacelle,
wherein when a fluid comes into contact with the exterior surface, the plurality of ports is configured to direct the fluid from the exterior surface to the interior of the nacelle.

21. The nacelle of Claim 20, further comprising one or more shields, wherein the one or more shields are configured to block fluid flow through at least a portion of ports of the plurality of ports.

22. The nacelle of Claim 21, wherein the one or more shields are located on one of the interior surface and the exterior surface of the nacelle.

23. The nacelle of Claim 21, wherein the one or more shields are configured to block a flow of the fluid due to a mechanical actuation.

24. The nacelle of Claim 23, wherein the mechanical actuation comprises an azimuthal shift of the one or more shields.

25. The nacelle of Claim 23, wherein the mechanical actuation is prompted by a user input.

26. The nacelle of Claim 23, wherein the mechanical actuation is autonomously triggered based at least in part on one or more flight factors, the one or more flight factors including wind direction, wind speed, air pressure change, engine efficiency, internal-external nacelle pressure difference, aircraft speed, flight duration, flight altitude, engine fan speed, engine thrust, or any combination thereof.

27. The nacelle of Claim 23, wherein the mechanical actuation is based at least in part on a flight phase, wherein the flight phase is selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

28. The nacelle of Claim 23, wherein the one or more shields are configured such that the mechanical actuation causes the one or more shields to transition among one or more configurations selected from a group consisting of:

an open configuration, in which the one or more shields are positioned such that fluid may flow through each port of the plurality of ports,

a partially open configuration, in which the one or more shields are positioned to block fluid flow through at least a portion of ports of the plurality of ports, and

a closed configuration, in which the one or more shields are positioned to block fluid flow through each port of the plurality of ports.

29. The nacelle of Claim 28, wherein a desired configuration of the one or more shields is selected based at least in part on a flight phase, wherein the flight phase is selected from a group consisting of: taxi, takeoff, climb, cruise, descent, and landing.

30. The nacelle of Claim 20, wherein the nacelle further comprises an inlet, wherein the inlet is configured to receive a main fluid flow, wherein the main fluid flow is characterized by having an interior flow direction from a first end to a second end of the nacelle, and wherein the plurality of ports is configured to direct the fluid, at least partially, in the interior flow direction.

31. The nacelle of Claim 30, wherein at least one port of the plurality of ports extends, at least partially, in the interior flow direction.

32. The nacelle of Claim 30, wherein at least one port of the plurality of ports comprises:
a first section proximal to the exterior surface; and
a second section proximal to the interior surface,
wherein the first section extends substantially radially to a centerline of the nacelle,
wherein the second section extends, at least partially, in the interior flow direction.

33. A method of inhibiting formation of ground vortices for a nacelle, comprising:
directing a fluid, via a plurality of ports, from an exterior surface of the nacelle to an interior of the nacelle based at least in part on a pressure difference between the exterior surface and the interior.

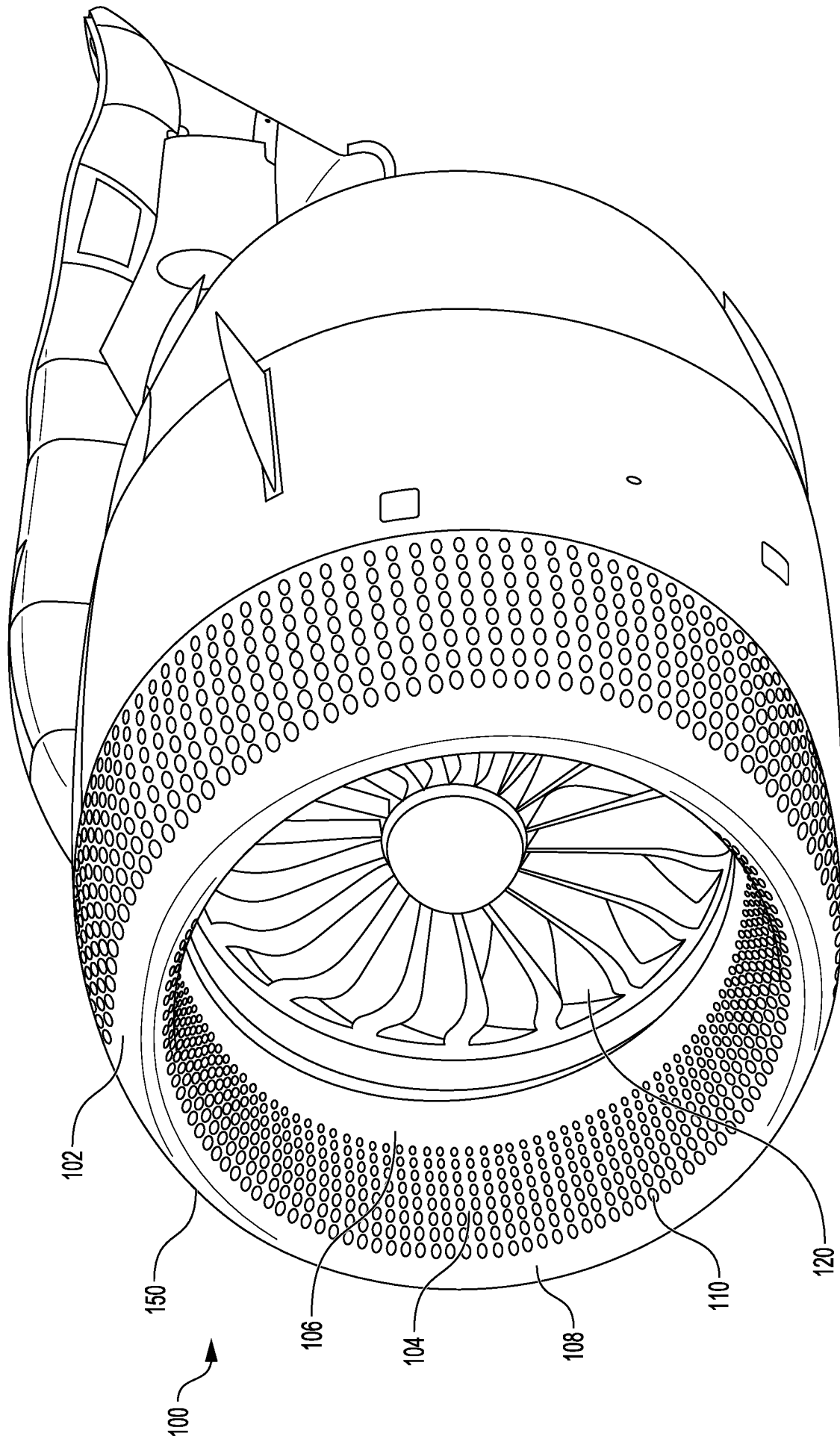
34. The method of Claim 33, wherein directing the fluid via the plurality of ports comprises directing a fluid, at least partially, in an internal flow direction.

35. The method of Claim 33, further comprising positioning one or more shields such that at least a section of the plurality of ports is blocked.

36. The method of Claim 35, further comprising:

determining a flight phase, the flight phase being selected from a group consisting of taxi, takeoff, climb, cruise, descent, and landing; and

shifting the one or more shields via a mechanical actuation based at least in part on the flight phase.



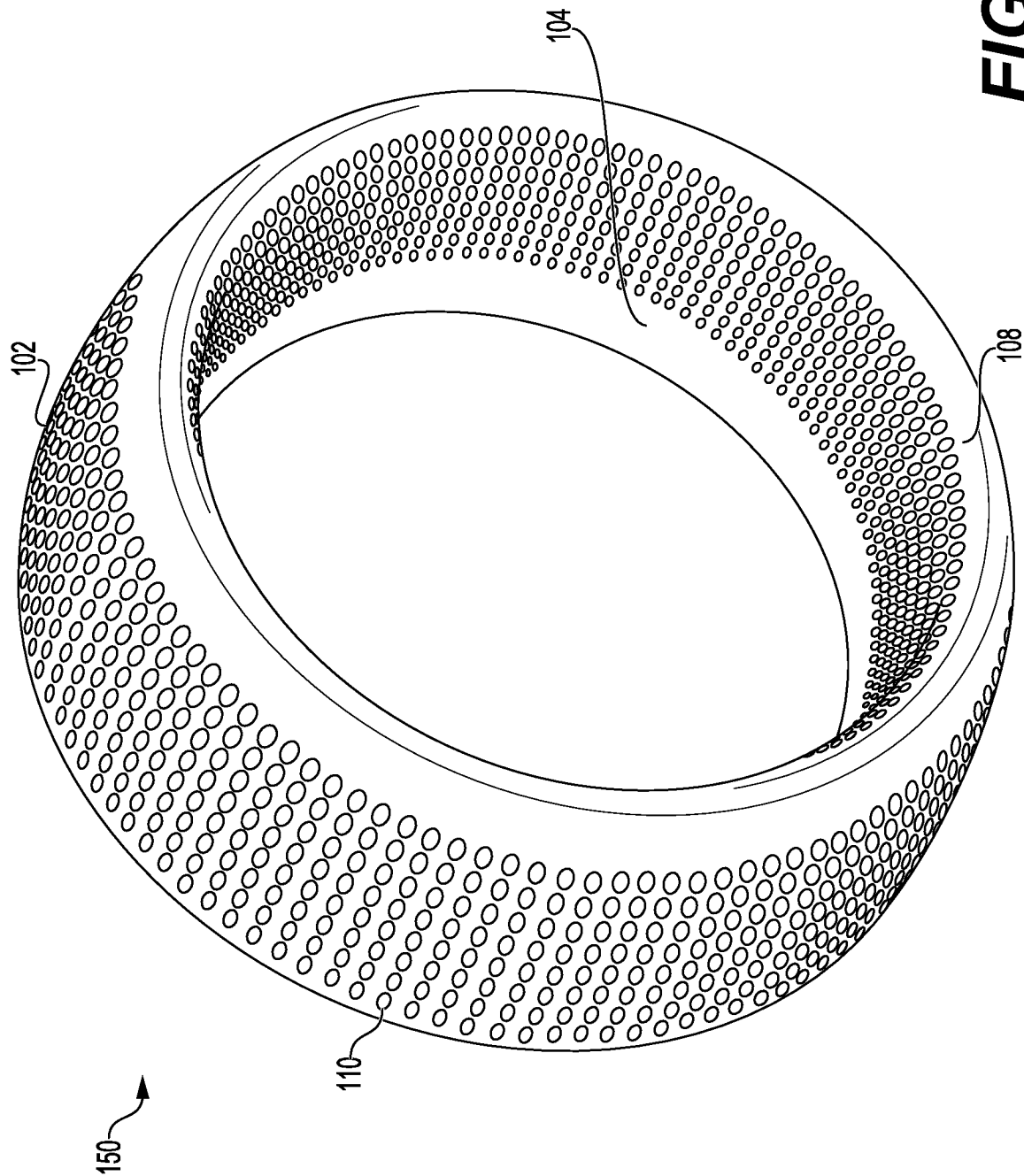
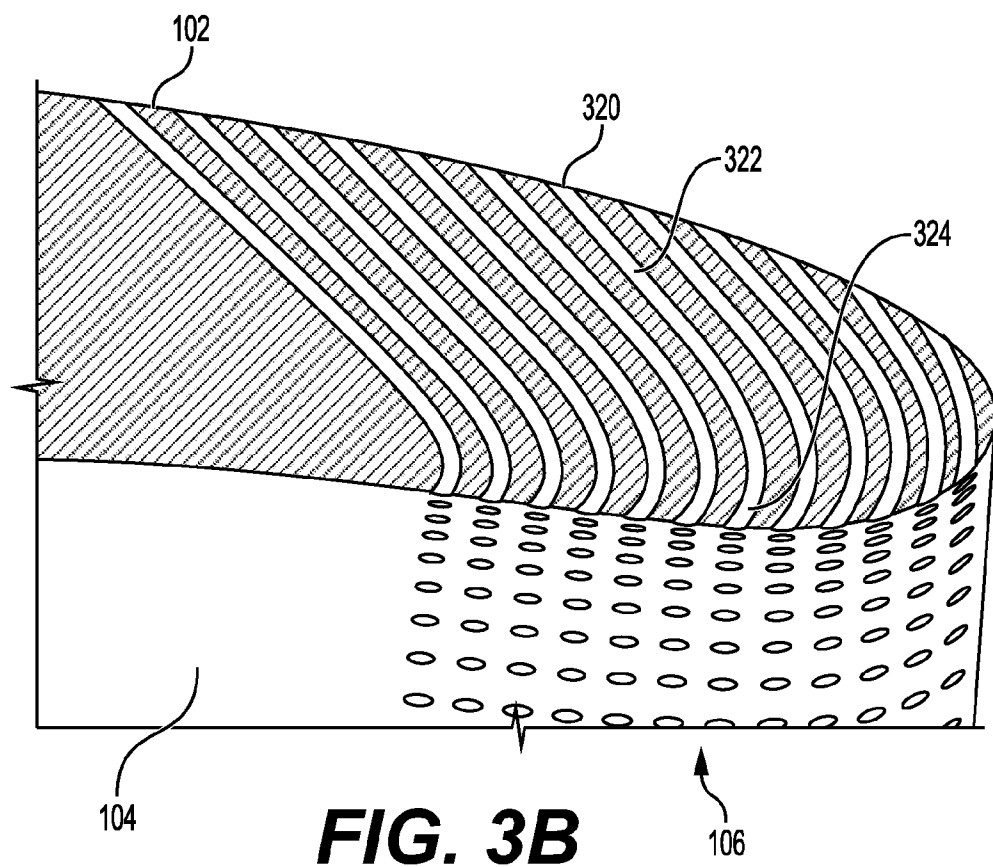
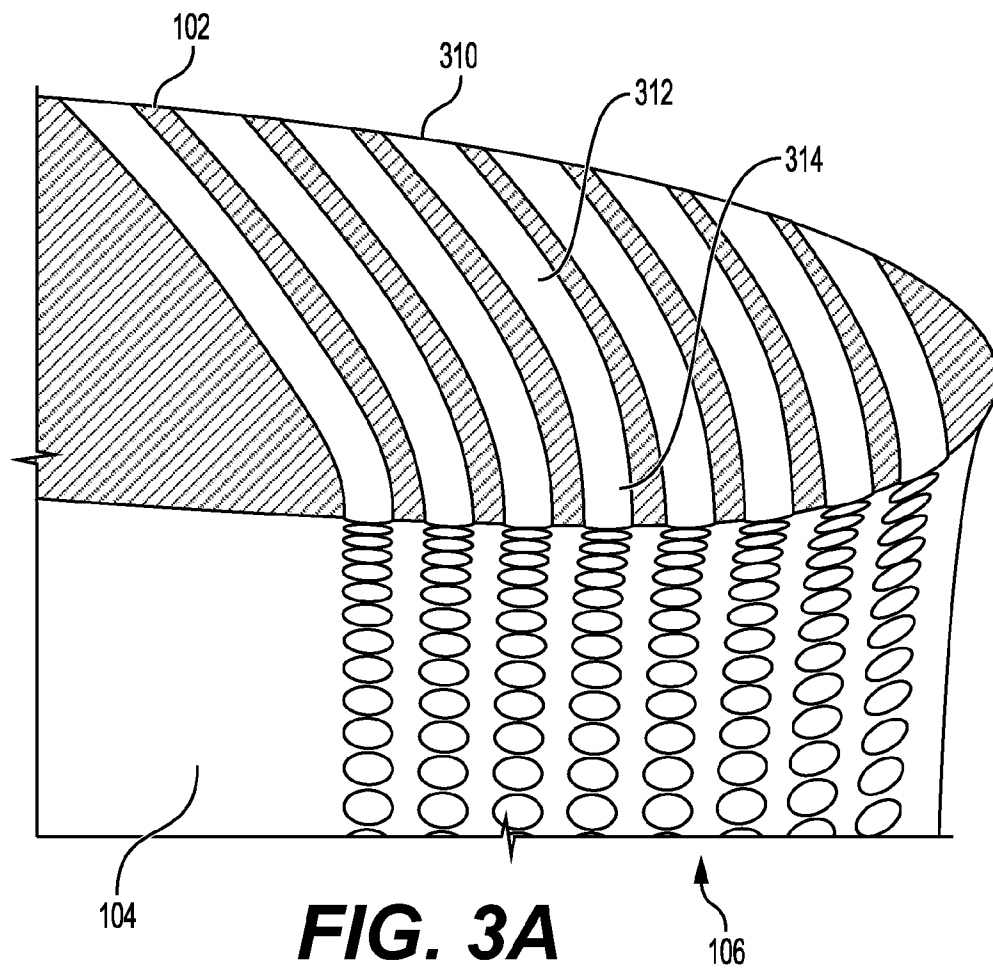


FIG. 2



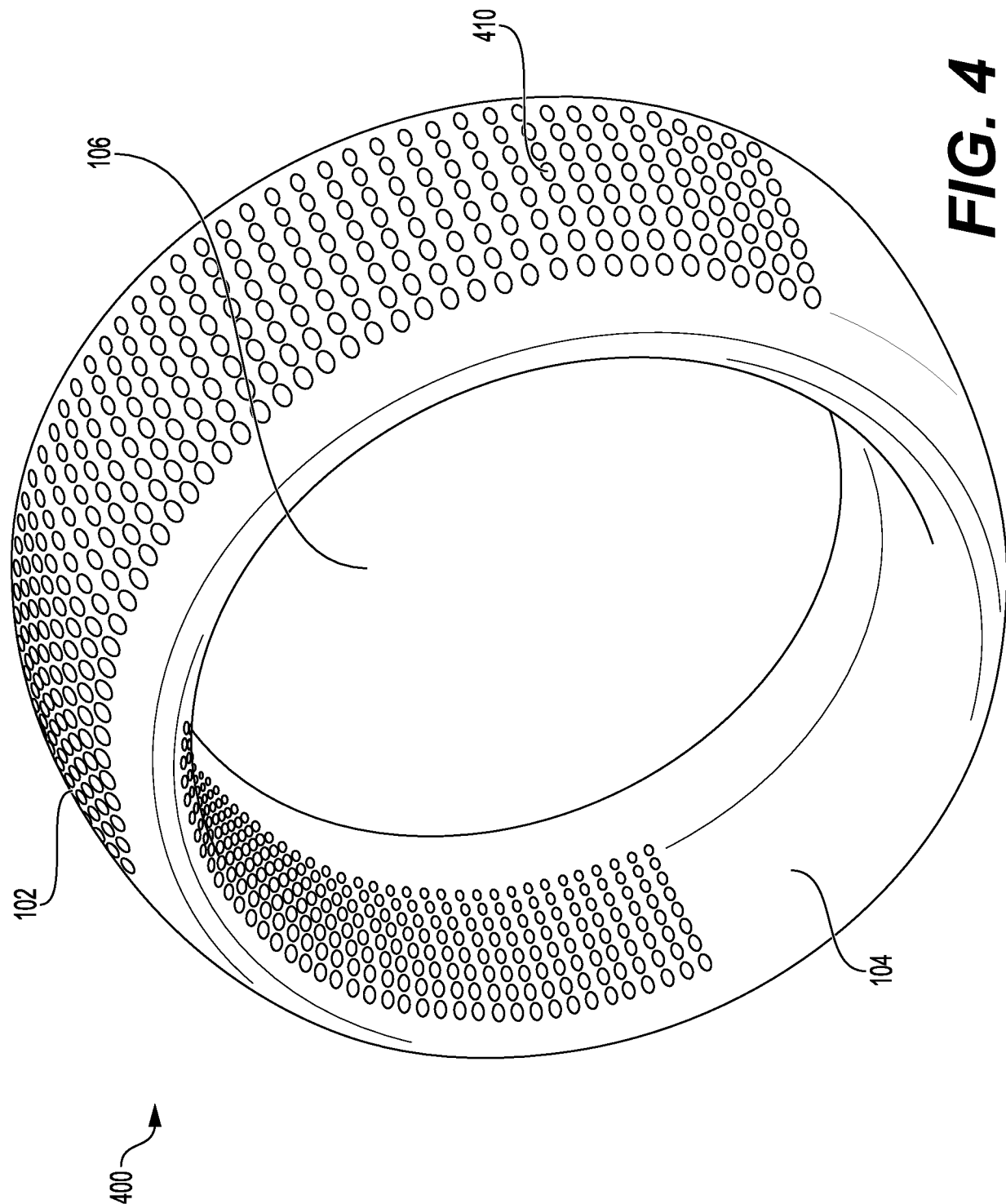
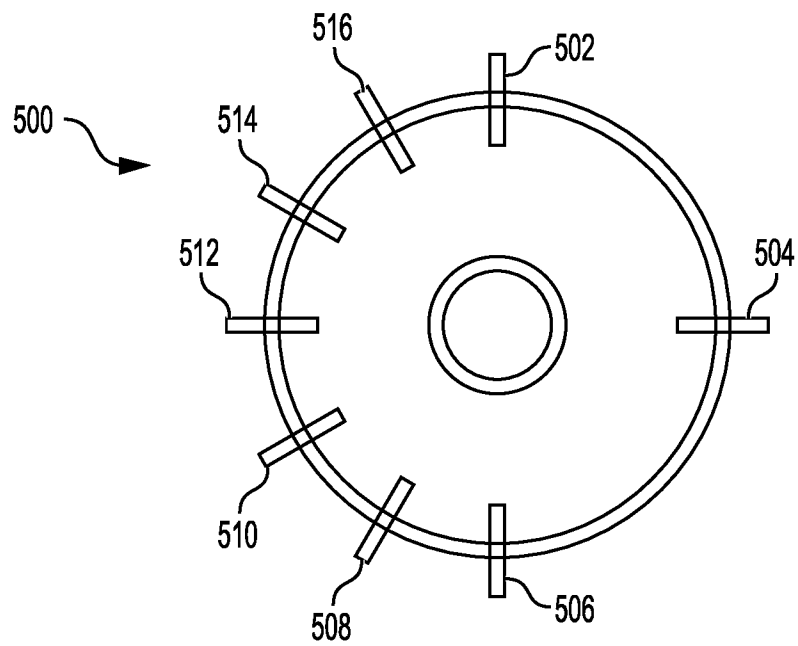


FIG. 4

**FIG. 5**

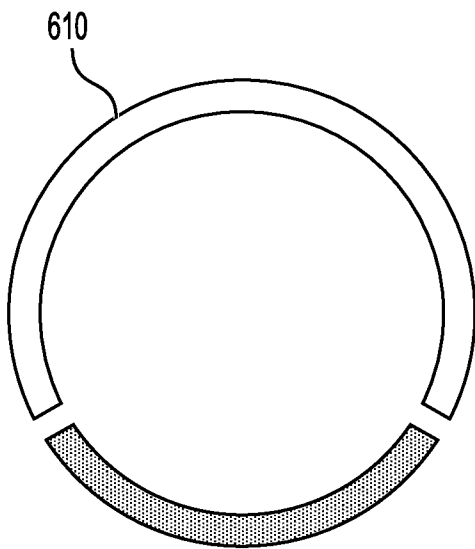


FIG. 6A

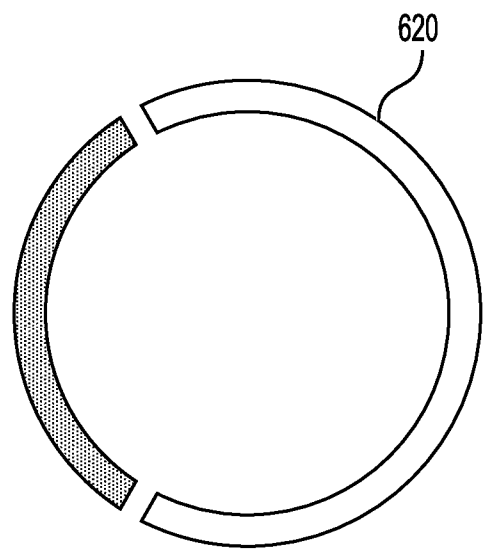


FIG. 6B

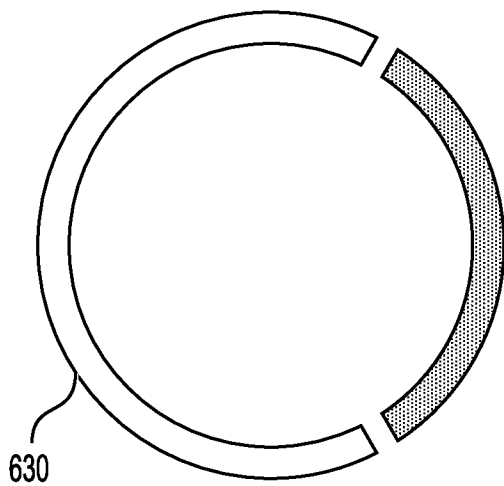


FIG. 6C

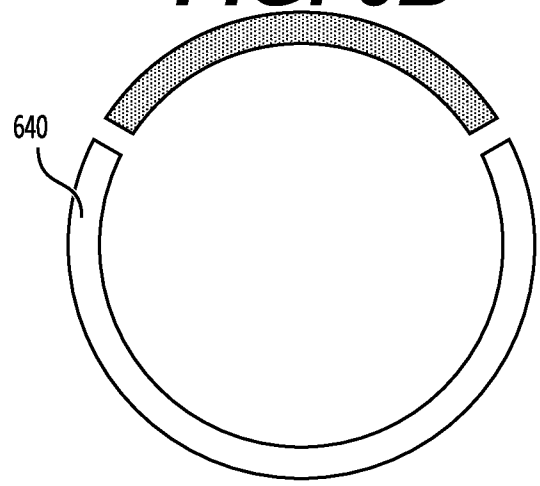


FIG. 6D

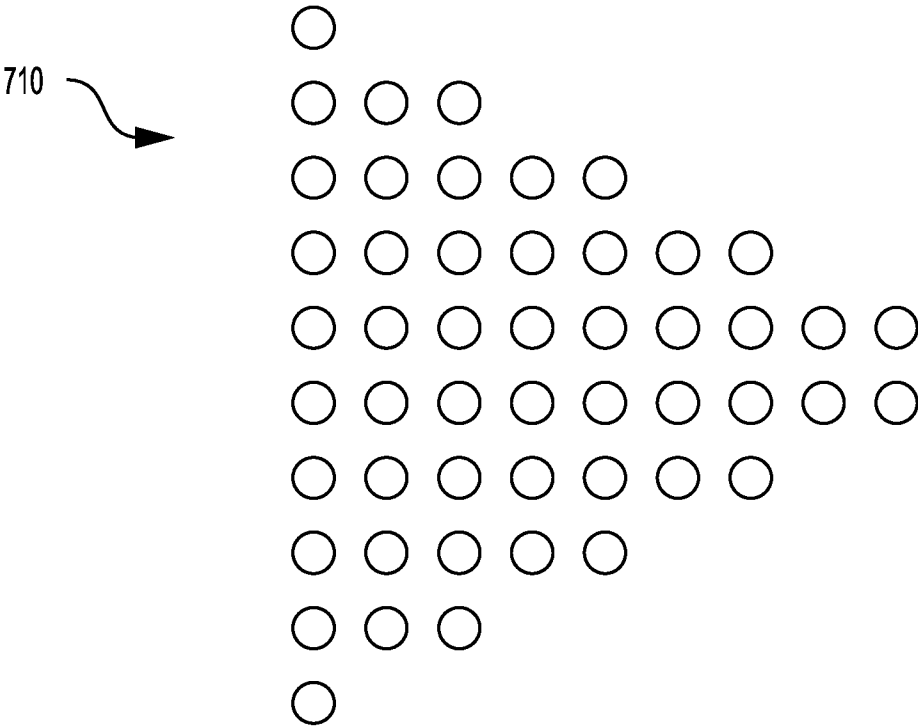


FIG. 7A

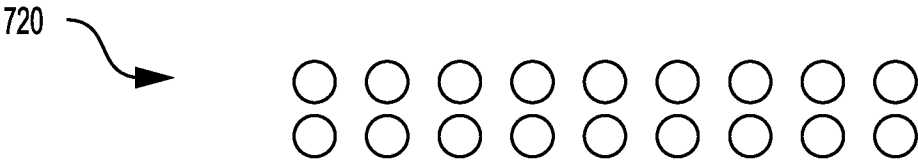


FIG. 7B

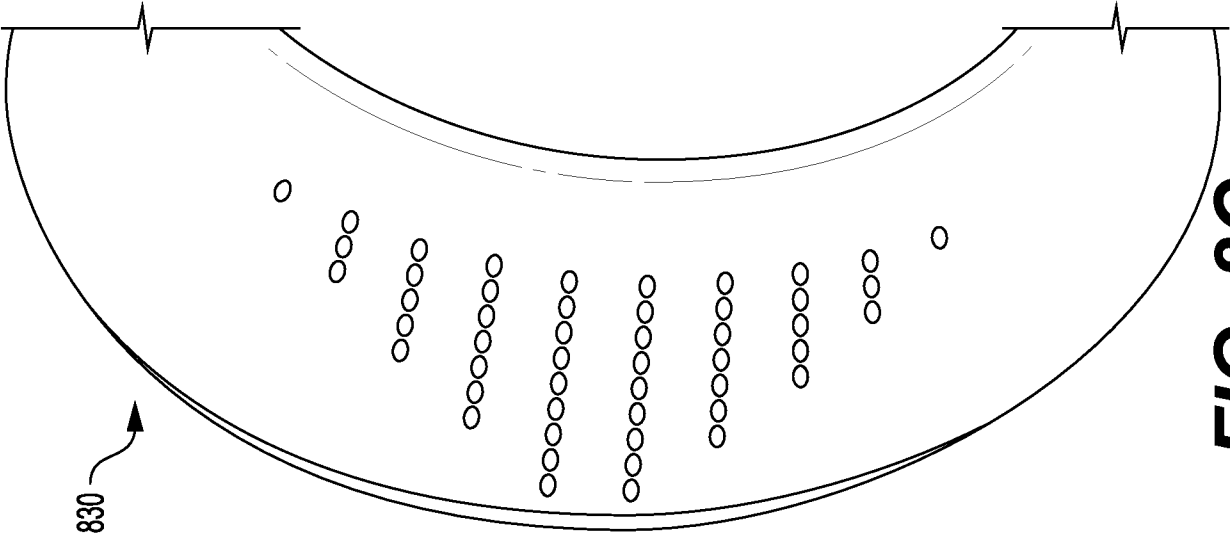


FIG. 8C

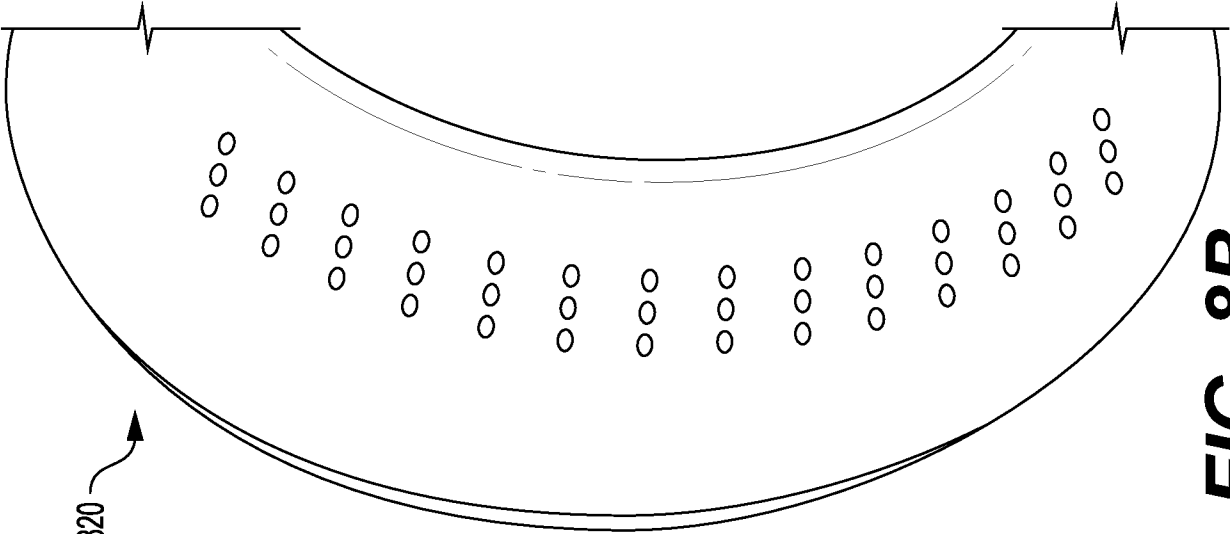


FIG. 8B

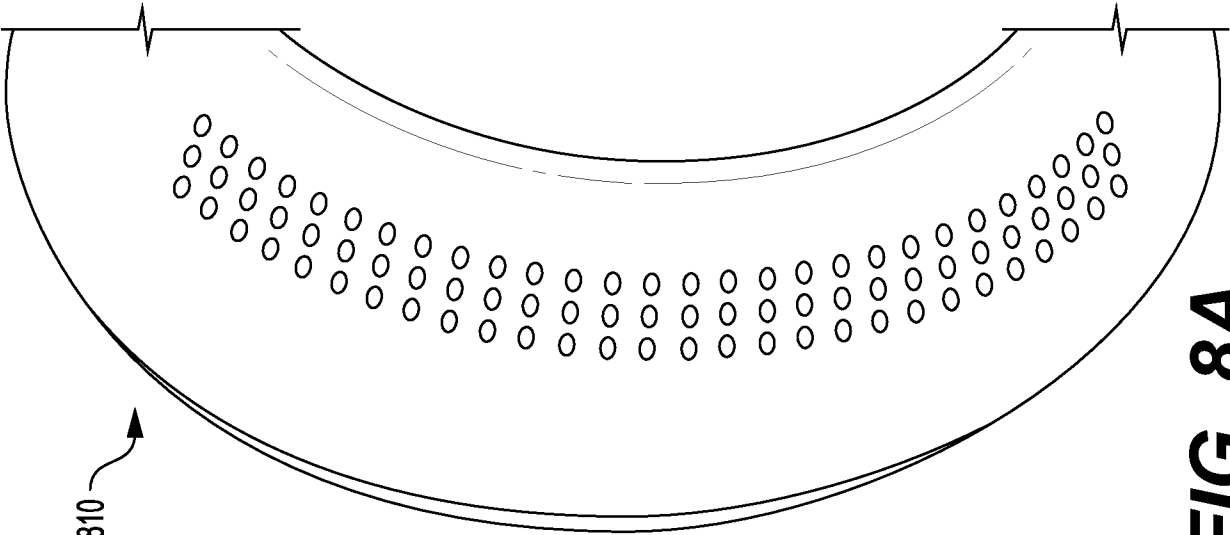


FIG. 8A

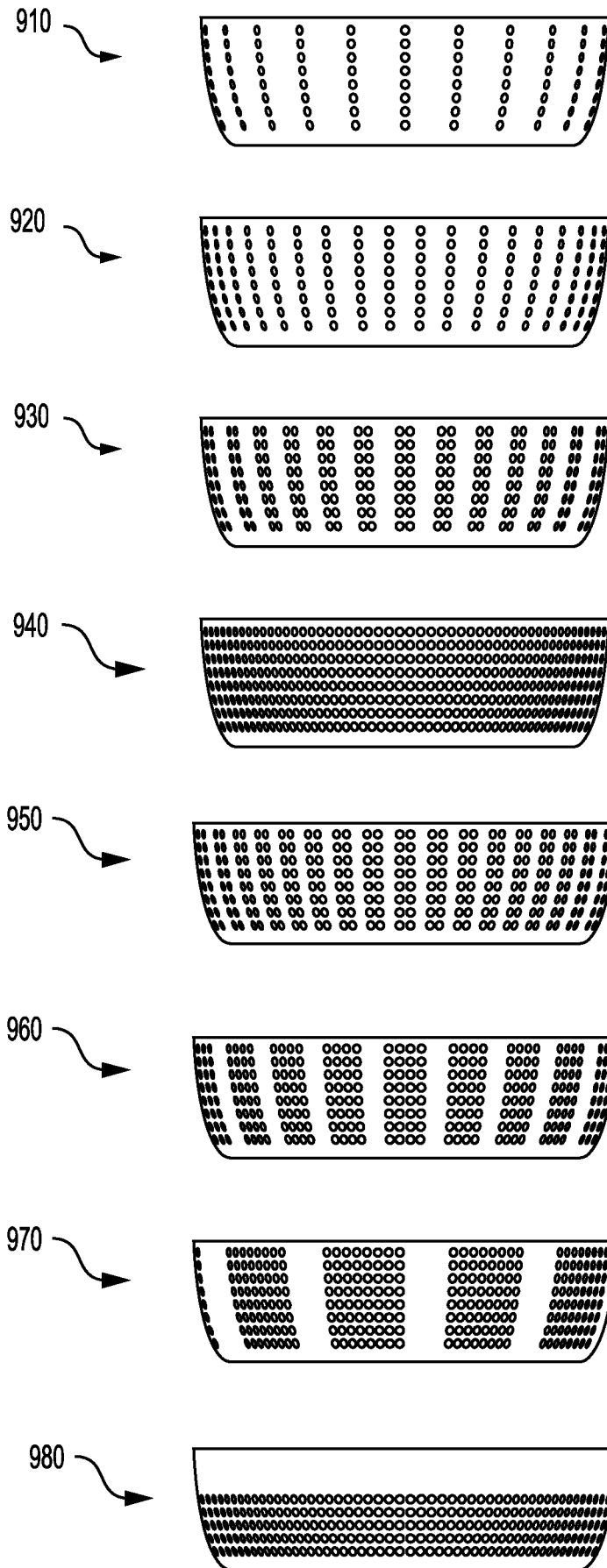
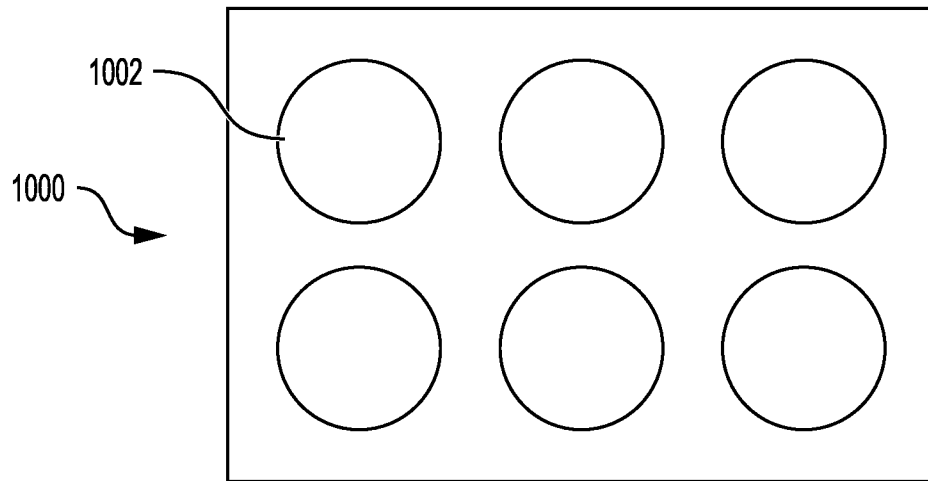
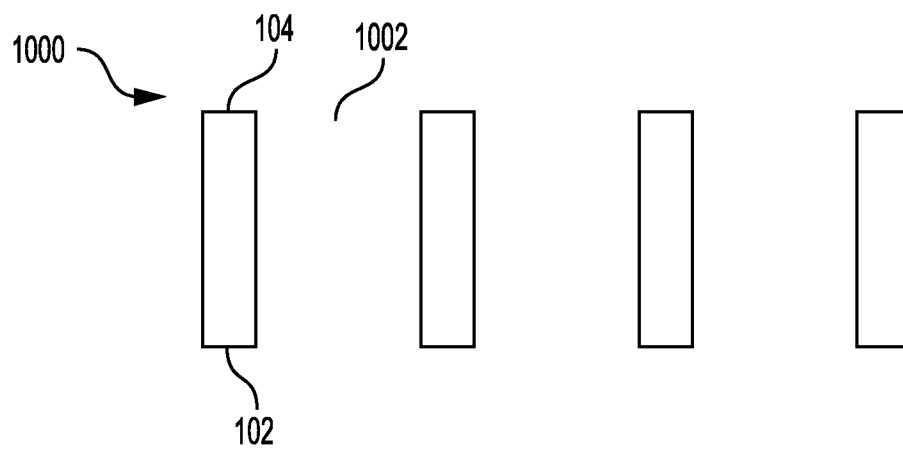


FIG. 9

**FIG. 10A****FIG. 10B**

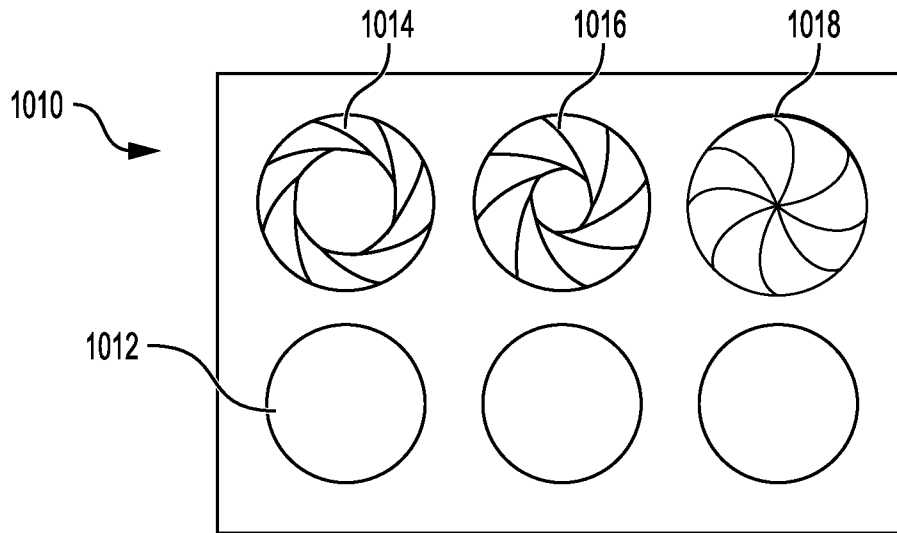
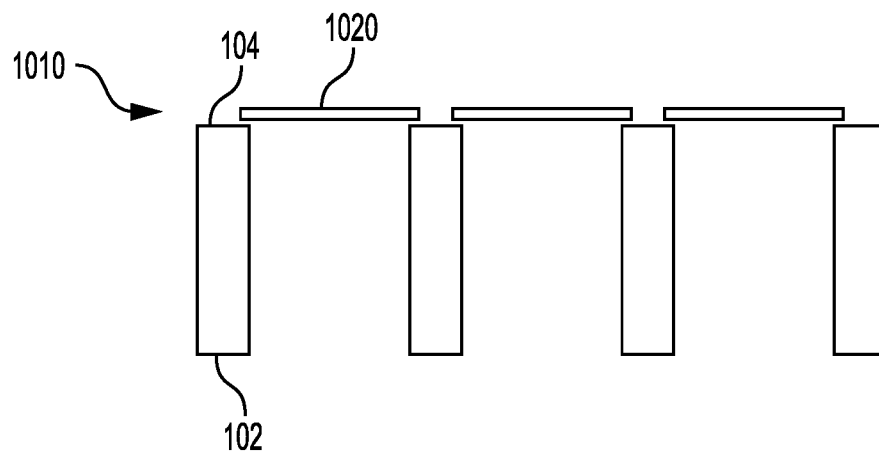
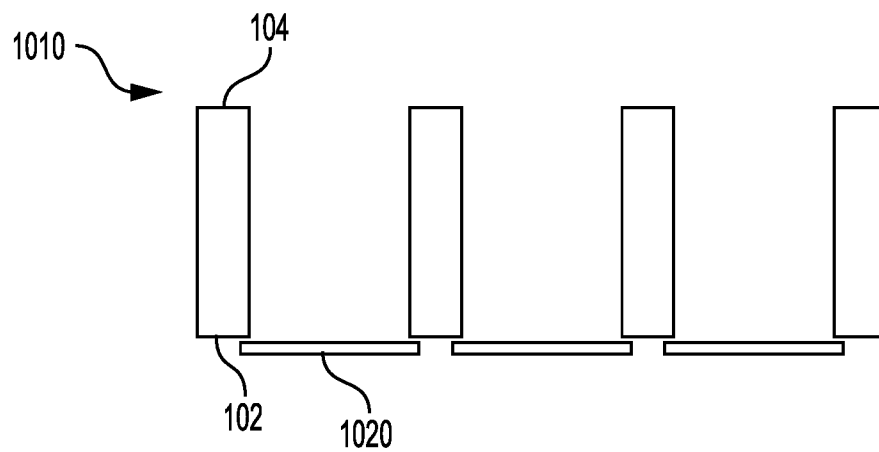
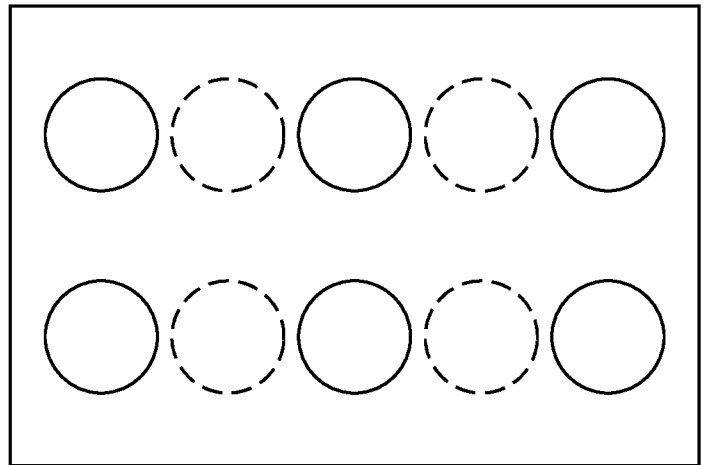
**FIG. 10C****FIG. 10D****FIG. 10E**

FIG. 11A

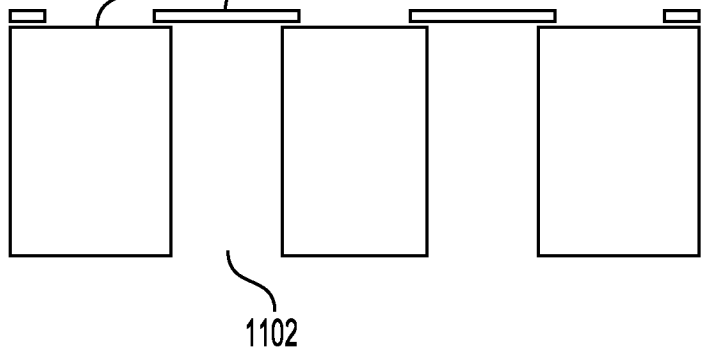
1100

**FIG. 11B**

1100

1104

1106

**FIG. 11C**

1110

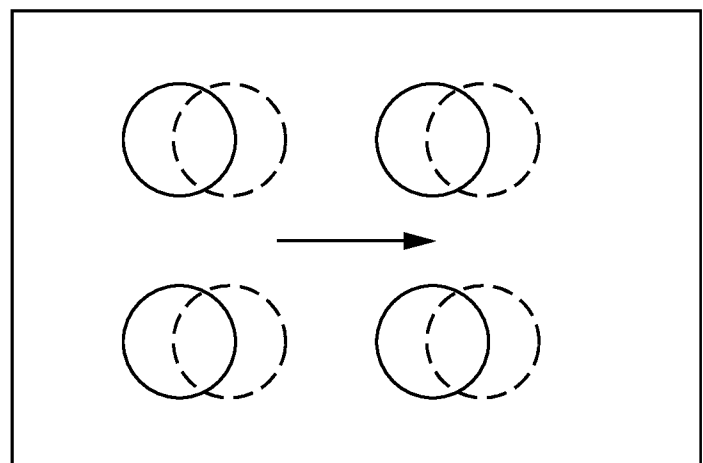


FIG. 11D

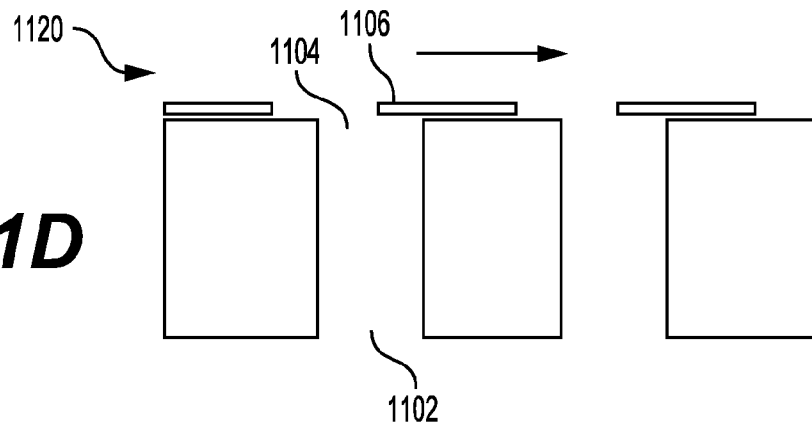


FIG. 11E

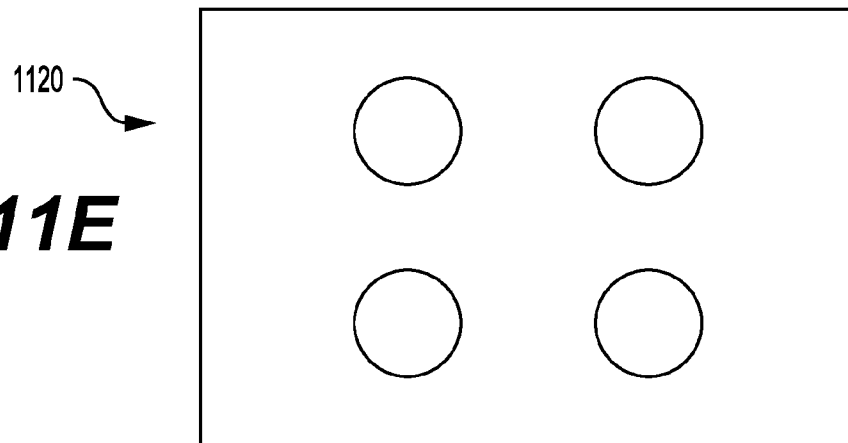
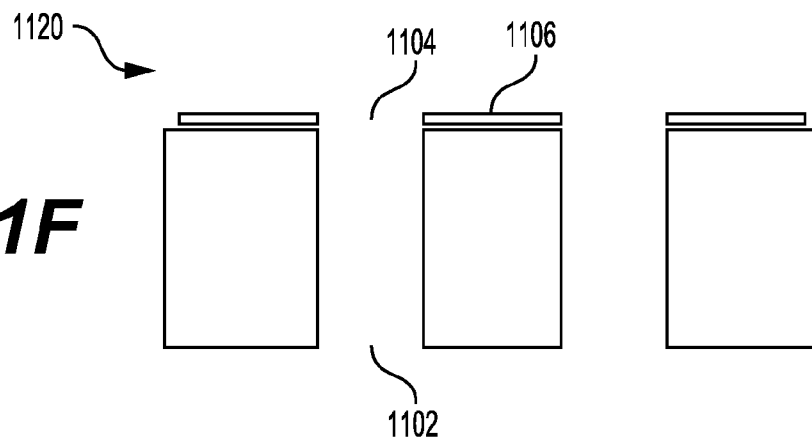
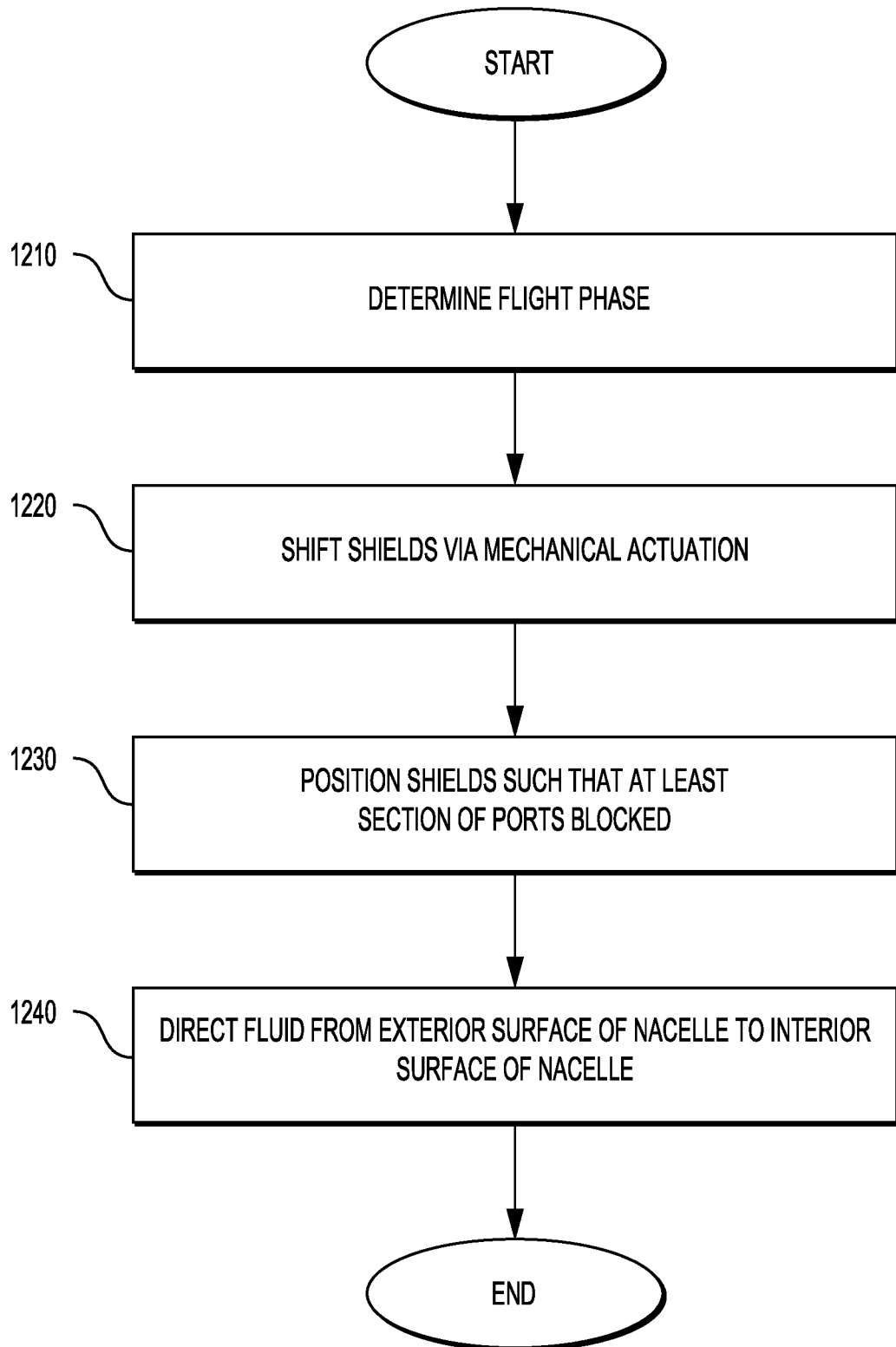


FIG. 11F



**FIG. 12**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/056379

A. CLASSIFICATION OF SUBJECT MATTER

IPC: **B64D 33/02** (2023.01); **B64D 29/00** (2023.01); **B64C 21/02** (2023.01); **F01D 17/00** (2023.01); **F02C 7/04** (2023.01)
CPC: **B64D 33/02**; **B64D 29/00**; **B64C 21/02**; **F02C 7/04**; **F01D 17/00**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2020/113110 A1 (GEORGIA TECH RESEARCH CORPORATION) 04 June 2020 (04.06.2020)	1-11, 13-24, 26-36
Y	entire document	12, 25
Y	US 2017/0158341 A1 (THE BOEING COMPANY) 08 June 2017 (08.06.2017)	12, 25
Y	entire document	
A	US 2009/0121083 A1 (JAIN) 14 May 2009 (14.05.2009)	1-36
A	entire document	
A	GB 579657 A (POWER JETS LTD et al.) 12 August 1946 (12.08.1946)	1-36
A	entire document	
A	US 2017/0001730 A1 (ROLLS-ROYCE PLC) 05 January 2017 (05.01.2017)	1-36
A	entire document	



Further documents are listed in the continuation of Box C.



See patent family annex.

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“O” document referring to an oral disclosure, use, exhibition or other means
“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

08 January 2025 (08.01.2025)

Date of mailing of the international search report

16 January 2025 (16.01.2025)

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