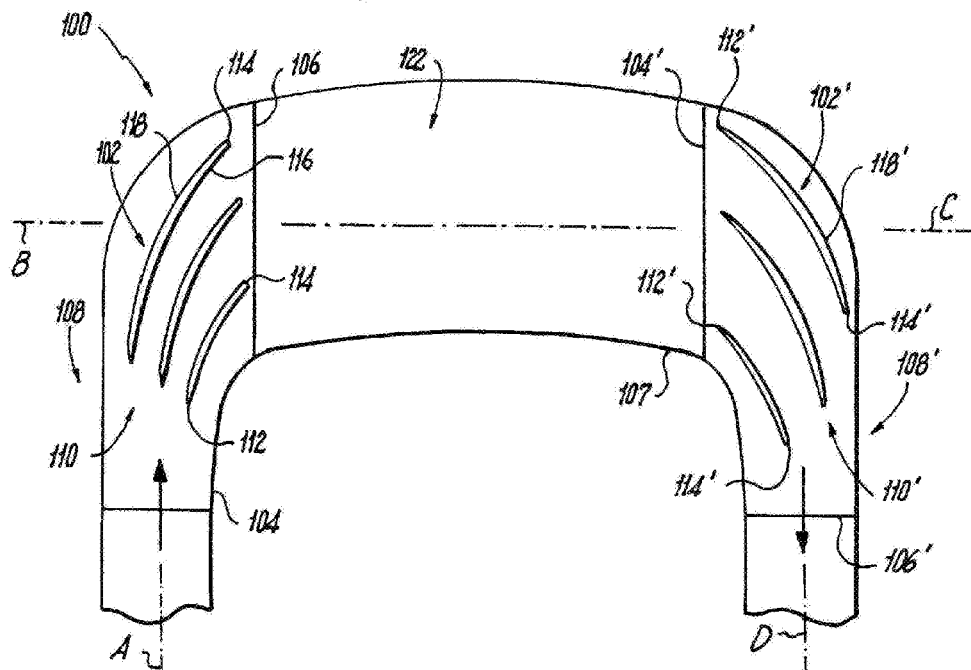




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(19) **United States**(12) **Patent Application Publication**
Herring(10) **Pub. No.: US 2017/0198988 A1**(43) **Pub. Date: Jul. 13, 2017**(54) **VANES FOR HEAT EXCHANGERS**(52) **U.S. Cl.**(71) Applicant: **Hamilton Sundstrand Corporation,**
Charlotte, NC (US)CPC *F28F 9/0268* (2013.01); *F28F 9/028*
(2013.01); *F28F 13/003* (2013.01)(72) Inventor: **Neal R. Herring,** East Hampton, CT
(US)(57) **ABSTRACT**(21) Appl. No.: **14/994,694**(22) Filed: **Jan. 13, 2016**

A heat exchanger includes a vane positioned between an inlet and an outlet of a heat exchanger manifold. The vane includes a leading edge proximate the inlet and a trailing edge proximate the outlet. The vane includes opposing first and second surfaces between the leading and trailing edges. The first and second surfaces are porous to provide fluidic communication between the first surface and the second surface to resist fluid separation along the first surface and/or the second surface to minimize fluid pressure drop between the inlet and the outlet of the manifold.

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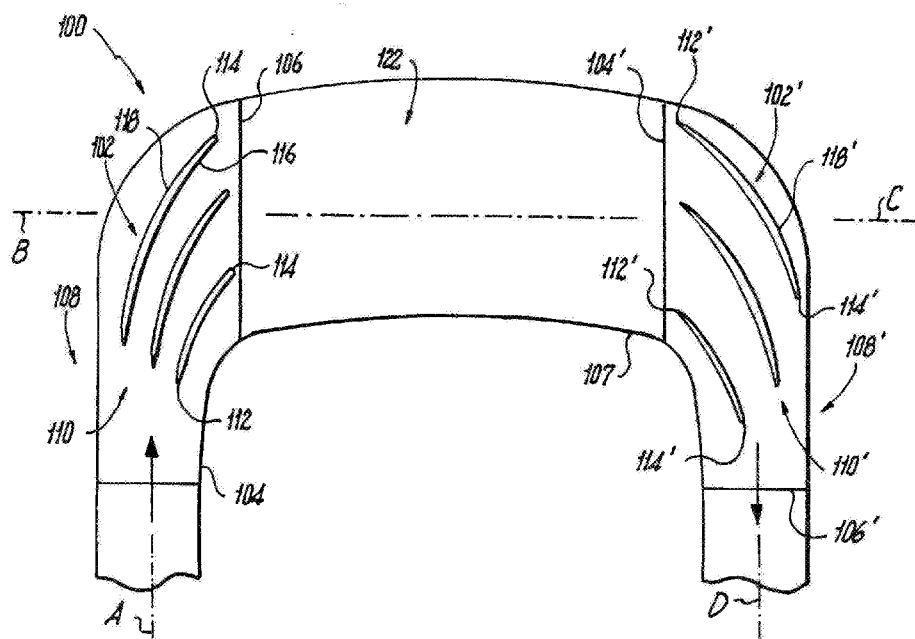


Fig. 1

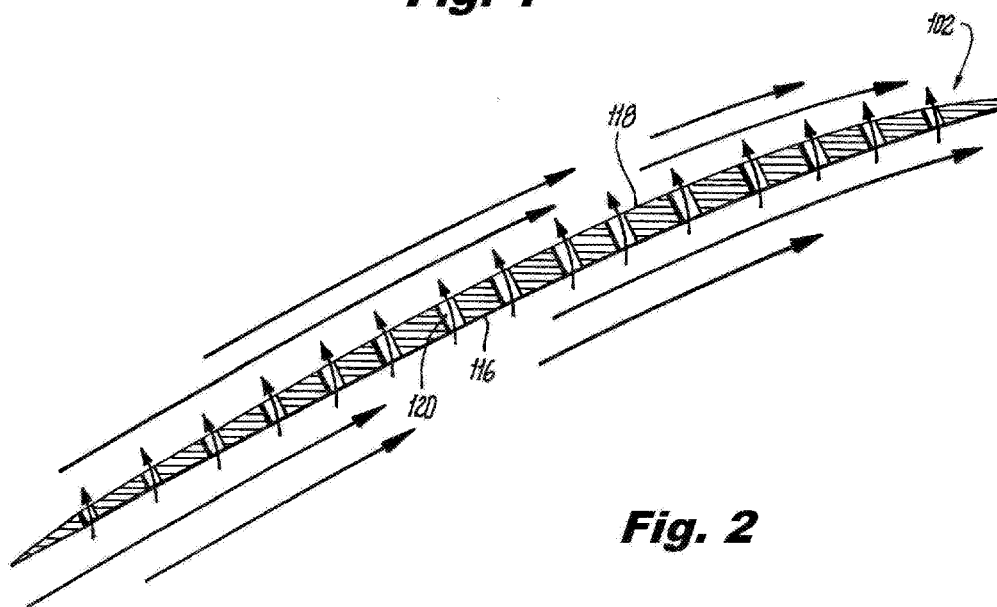


Fig. 2

Fig. 3

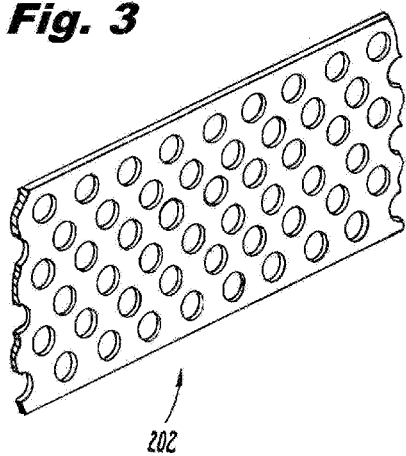


Fig. 4

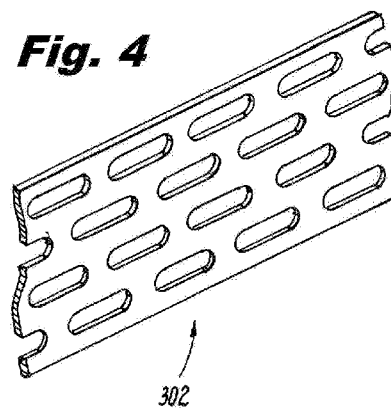


Fig. 5

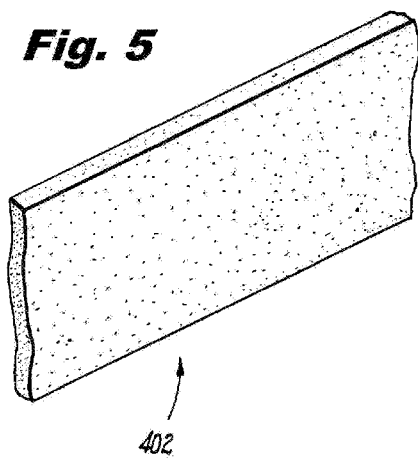
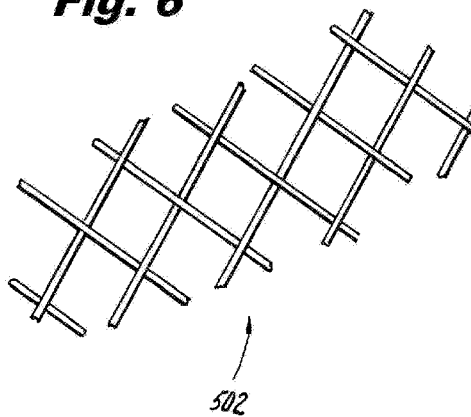


Fig. 6



VANES FOR HEAT EXCHANGERS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to heat exchangers, and, in particular, to vanes for manifolds in heat exchangers.

[0003] 2. Description of Related Art

[0004] Heat exchangers are used in a variety of systems, for example, in engine and environmental control systems of aircraft. These systems tend to require continual improvement in heat transfer performance, reductions in pressure loss, and reductions in size and weight. Heat exchangers can include manifolds leading into and/or out of the heat exchanger core. These manifolds can direct fluid flow into and out of the heat exchanger core and can cause a pressure drop between an inlet pipe and the heat exchanger core.

[0005] Such conventional methods and systems have generally been considered satisfactory for their intended purpose. However, there is still a need in the art for systems and methods that allow for improved heat exchangers. The present invention provides a solution for these problems.

SUMMARY OF THE INVENTION

[0006] A heat exchanger includes a vane positioned between an inlet and an outlet of a heat exchanger manifold. The vane includes a leading edge proximate the inlet and a trailing edge proximate the outlet. The vane includes opposing first and second surfaces between the leading and trailing edges. The first and second surfaces are porous to provide fluidic communication between the first surface and the second surface to resist fluid separation along the first surface and/or the second surface to minimize fluid pressure drop between the inlet and the outlet of the manifold.

[0007] A flow path can be defined between the inlet and the outlet of the heat exchanger manifold. The inlet can define an inlet axis substantially parallel to the flow path at the inlet. The outlet can define an outlet axis angled with respect to the inlet axis. In accordance with some embodiments, the porosity of the vane is defined by at least one of a plurality of apertures, a foam structure, slot perforations, hole perforations, and a wire mesh. It is contemplated that the vane can be a first vane and that the heat exchanger can include additional vanes positioned between the inlet and the outlet of the heat exchanger manifold. The additional vanes can be similar to the first vane described above. The first surface can be a concave surface and the second surface can be a convex surface.

[0008] The heat exchanger can include a heat exchanger core operatively connected to and in fluid communication with the outlet of the manifold. The heat exchanger can include a second-manifold vane positioned between an inlet and an outlet of a second heat exchanger manifold. The inlet of the second heat exchanger manifold can be operatively connected to an outlet of the heat exchanger core. The second heat exchanger manifold can define a second-manifold flow path between the inlet and the outlet of the second heat exchanger manifold. The inlet of the second heat exchanger manifold can define a second-manifold inlet axis substantially parallel to the second-manifold flow path at the outlet of the heat exchanger core. The outlet of the second heat exchanger manifold can define a second-manifold outlet axis angled with respect to the second-manifold inlet axis. The second-manifold vane can include a leading edge

proximate the outlet of the heat exchanger core and a trailing edge proximate the outlet of the second heat exchanger manifold. The second-manifold vane can include porous first and second surfaces, similar to the vane described above. The porosity of the second-manifold vane can be defined by apertures.

[0009] In accordance with some embodiments, the second-manifold vane is a first second-manifold vane. The heat exchanger can include additional second-manifold vanes positioned between an inlet and an outlet of the second heat exchanger manifold. The additional second-manifold vanes can be similar to the first second-manifold vane described above.

[0010] In accordance with another aspect, a method of manufacturing a vane for a heat exchanger, similar to the vanes described above, includes forming a vane body having a leading edge and a trailing edge with a first surface and an opposing second surface between the leading and trailing edges. The first and second surfaces are porous to provide fluidic communication between the first surface and the second surface. The forming can be via additive manufacturing, for example, direct metal laser sintering.

[0011] These and other features of the systems and methods of the subject invention will become more readily apparent to those skilled in the art from the following detailed description of the preferred embodiments taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that those skilled in the art to which the subject invention appertains will readily understand how to make and use the devices and methods of the subject invention without undue experimentation, preferred embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

[0013] FIG. 1 is a top view of a schematic depiction of an exemplary embodiment of a heat exchanger constructed in accordance with the present disclosure showing a plurality of vanes in the heat exchanger manifold;

[0014] FIG. 2 is a cross-sectional view of an embodiment of the vanes of FIG. 1, showing apertures between the surfaces of the vane;

[0015] FIG. 3 is a schematic perspective view of a portion of another embodiment of a vane constructed in accordance with the present disclosure, showing the vane as a sheet with hole-shaped perforations;

[0016] FIG. 4 is a schematic perspective view of a portion of another embodiment of a vane constructed in accordance with the present disclosure, showing the vane as a sheet with slot-shaped perforations;

[0017] FIG. 5 is a schematic perspective view of a portion of another embodiment of a vane constructed in accordance with the present disclosure, showing the vane with a porous foam structure; and FIG. 6 is a schematic perspective view of a portion of another embodiment of a vane constructed in accordance with the present disclosure, showing the vane having a wire mesh structure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Reference will now be made to the drawings wherein like reference numerals identify similar structural features or aspects of the subject disclosure. For purposes of

explanation and illustration, and not limitation, a perspective view of an exemplary embodiment of a heat exchanger in accordance with the disclosure is shown in FIG. 1 and is designated generally by reference character 100. Other embodiments of heat exchanger 100 in accordance with the disclosure, or aspects thereof, are provided in FIGS. 2-6, as will be described. The heat exchangers described herein provide for reduced fluid pressure drop and increased flow uniformity as compared with traditional heat exchangers.

[0019] As shown in FIG. 1, a heat exchanger 100 includes vanes 102 positioned between an inlet 104 and an outlet 106 of a heat exchanger manifold 108. A flow path 110 is defined between inlet 104 and outlet 106 of heat exchanger manifold 108. Inlet 104 defines an inlet axis A substantially parallel to the flow path at inlet 104. Outlet 106 defines an outlet axis B angled with respect to inlet axis A. In an embodiment, the angle between the inlet axis A and the outlet axis B is about 90 degrees. Each vane 102 includes a leading edge 112 proximate inlet 104 and a trailing edge 114 proximate outlet 106. Each vane 102 includes opposing first and second surfaces, 116 and 118 respectively, between leading and trailing edges, 112 and 114, respectively. First surface 116 is a concave surface and second surface 118 is a convex surface. It is contemplated that manifold 108 can include any suitable number of vanes 102, for example, manifold 108 can include a single vane 102 or a plurality of vanes 102. It is contemplated that vanes can all be porous vanes 102, as will be describe below, or the vanes can be a mixture of porous and non-porous vanes. In accordance with an embodiment, it is also contemplated both porous and non-porous sections can be included in a single vane.

[0020] With continued reference to FIG. 1, heat exchanger 100 includes a heat exchanger core 122 operatively connected to and in fluid communication with outlet 106 of manifold 102. It is contemplated that heat exchanger core 122 can be a plate-fin heat exchanger core, a counter-flow heat exchanger core, or any other suitable heat exchanger core. Heat exchanger 100 includes a second-manifold vane 102' positioned between an inlet 104' and an outlet 106' of a second heat exchanger manifold 108'. Inlet 104' of second heat exchanger manifold 108' is connected to an outlet 107 of heat exchanger core 122. Second heat exchanger manifold 108' defines a second-manifold flow path 110' between inlet 104' and outlet 106' of second heat exchanger manifold 108'. Inlet 104' of the second heat exchanger manifold 108' defines a second-manifold inlet axis C substantially parallel to the second-manifold flow path at outlet 107 of heat exchanger core 122. Outlet 106' of second heat exchanger manifold 108' defines a second-manifold outlet axis D angled with respect to second-manifold inlet axis C. The heat exchanger 100 being configured, in one embodiment, so that the flow out of the outlet 106' along axis D is substantially 180 degrees to the flow into the inlet 104 along axis A.

[0021] While vanes 102 and 102' are shown with varying thicknesses, those skilled in the art will readily appreciate that vanes 102 and/or 102' can be uniform in thickness. It is contemplated that manifolds 108 and/or 108' can have a variety of suitable shapes, for example, they can be semi-hemispherical, include a diffuser, or be any other suitable shape or variation depending on the design space provided. Manifolds 108 and/or 108' and vanes 102 and/or 102' can be made from a variety of suitable metals or alloys thereof, such as, nickel, copper, titanium, steel, and/or aluminum. In accordance with some embodiments, it is contemplated that

the leading and trailing edges of vanes 102 and/or 102' can begin and end anywhere, as long as at least a portion of a given vane is positioned between the inlet and the outlet. It is also contemplated that the vanes may all be of the same length and spacing, or may have different lengths and spacing to achieve the desired flow distribution with minimal pressure drop.

[0022] As shown in FIG. 2, concave and convex surfaces, 116 and 118, respectively, of each vane 102, are porous to provide fluidic communication between concave surface 116 to convex surface 118, shown schematically by arrows. The fluid flow from concave surface 116 to convex surface 118 acts to resist fluid separation on along convex 118 surface and minimizes fluid pressure drop between inlet 104 and outlet 106 of manifold 108. With traditional heat exchanger vanes, fluid flow over the convex side of the vane tends to separate and can result increased pressure loss across the vane, and ultimately can result in increased pressure drop between the inlet and outlet of the manifold. The porosity of vane 102 acts as a flow control device to minimize separation from convex surface 118 and reduce the pressure loss across vane 102 in manifold 108 while still providing the desired flow distribution into heat exchanger core 122. In accordance with the embodiment in FIG. 2, the porosity in vane 102 is achieved using apertures 120 between concave and convex surfaces, 116 and 118, respectively.

[0023] As shown in FIGS. 3-6, it is contemplated that the porosity of vanes can be achieved with a variety of suitable geometries, for example, vanes can be a perforated sheet with either uniform or non-uniformly spaced holes, slits, or other features. In accordance with some embodiments, vanes 202 and 302 are sheets with hole-shaped or slot shaped perforations, shown in FIGS. 3 and 4, respectively. In accordance with the embodiment of FIG. 5, vanes 402 resemble the construction of open-cell foam and/or reticulated foam, where pores of the foam allow flow from one surface to the other. As shown in the embodiment of FIG. 6, vanes 502 include a wire mesh structure, similar to a metal screen.

[0024] With reference now to FIGS. 1 and 2, each of the second-manifold vanes 102' include a respective leading edge 112' proximate outlet 107 of heat exchanger core 122 and a respective trailing edge 114' proximate outlet 106' of second heat exchanger manifold 108'. Each second-manifold vane 102' includes respective porous concave and convex surfaces, 116' and 118', respectively, similar to vane 102 describe above. For example, one or more of second-manifold vanes 102' can include apertures, similar to apertures 120 in vane 102, described above. It is contemplated that manifold 108' can include any suitable number of vanes 102', for example, manifold 108' can include a single vane 102' or a plurality of vanes 102'. It is contemplated that vanes 102' can all be porous vanes, or vanes 102' can be a mixture of porous and non-porous vanes. In accordance with an embodiment, it is also contemplated that both porous and non-porous sections can be included in a single vane.

[0025] In accordance with another aspect, a method of manufacturing a vane, e.g. vanes 102 and/or 102', for a heat exchanger, e.g. heat exchanger 100, includes forming a vane body having a leading edge and a trailing edge, e.g. leading and trailing edges, 112/112' and 114/114', respectively, with a concave surface and an opposing convex surface, e.g. concave and convex surfaces 116/116' and 118/118', respectively, between the leading and trailing edges using additive

manufacturing, for example, direct metal laser sintering. It is contemplated that the vanes can be formed in conjunction with their respective heat exchanger manifolds, e.g. heat exchanger manifolds **108** and/or **108'**.

[0026] While vanes **102** and **102'** are shown and described herein as having an arcuate geometry, it is contemplated that vanes **102** and **102'** do not have to be continuously curved. Vanes **102** and **102'** can include straight sections, be entirely straight, or can create an s-curve, depending on the orientation of the inlet manifold, the core and the outlet manifold. Additionally, it is contemplated that while the flow path at inlet **104** is shown at ninety degrees with respect to core **122**, inlet **104** can be at a variety of angles with respect to core **122**. For example, they can be in direct alignment or at an angle less than or more than ninety degrees. This similarly can apply to the angle between core **122** and outlet **106'** of second heat exchanger manifold **108'**.

[0027] The methods and systems of the present disclosure, as described above and shown in the drawings, provide for heat exchanger manifolds with vanes having superior properties including reduced pressure drop and flow uniformity. While the apparatus and methods of the subject disclosure have been shown and described with reference to preferred embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the spirit and scope of the subject disclosure.

What is claimed is:

1. A heat exchanger comprising:
 - a vane positioned between an inlet and an outlet of a heat exchanger manifold, wherein the vane includes a leading edge proximate the inlet and a trailing edge proximate the outlet, and opposing first and second surfaces between the leading and trailing edges, wherein the first and second surfaces are porous to provide fluidic communication between the first surface and the second surface to resist fluid separation along at least one of the first surface or the second surface.
2. The heat exchanger as recited in claim 1, wherein a flow path is defined between the inlet and the outlet of the heat exchanger manifold, wherein the inlet defines an inlet axis substantially parallel to the flow path at the inlet, and wherein the outlet defines an outlet axis angled with respect to the inlet axis.
3. The heat exchanger as recited in claim 1, wherein the porosity of the vane is defined by a plurality of apertures.
4. The heat exchanger as recited in claim 1, wherein the porosity of the vane is defined by at least one of a foam structure, slot perforations, hole perforations, and a wire mesh.
5. The heat exchanger as recited in claim 1, wherein the first surface is a concave surface and the second surface is a convex surface.
6. The heat exchanger as recited in claim 1, further comprising additional vanes positioned between the inlet and the outlet of the heat exchanger manifold, wherein the vane is a first vane.
7. The heat exchanger as recited in claim 6, wherein the additional vanes each include a leading edge proximate the inlet and a trailing edge proximate the outlet, and opposing first and second surfaces between the leading and trailing edges, wherein the first and second surfaces are porous to provide fluidic communication between the first surface and

the second surface to resist fluid separation along at least one of the first surface or the second surface.

8. The heat exchanger as recited in claim 7, wherein the porosity of each of the additional vanes is defined by a plurality of apertures.

9. The heat exchanger as recited in claim 7, wherein the porosity each of the additional vanes is defined by at least one of a foam structure, slot perforations, hole perforations, and a wire mesh.

10. The heat exchanger as recited in claim 1, further comprising a heat exchanger core operatively connected to and in fluid communication with the outlet of the manifold.

11. The heat exchanger as recited in claim 10, further comprising a second-manifold vane positioned between an inlet and an outlet of a second heat exchanger manifold, wherein the inlet of the second heat exchanger manifold is operatively connected to an outlet of the heat exchanger core.

12. The heat exchanger as recited in claim 11, wherein the second heat exchanger manifold includes defines a second-manifold flow path between the inlet and the outlet of the second heat exchanger manifold, wherein the inlet of the second heat exchanger manifold defines a second-manifold inlet axis substantially parallel to the second-manifold flow path at the outlet of the heat exchanger core, and wherein the outlet of the second heat exchanger manifold defines a second-manifold outlet axis angled with respect to the second-manifold inlet axis.

13. The heat exchanger as recited in claim 11, wherein the second-manifold vane includes a leading edge proximate the outlet of the heat exchanger core and a trailing edge proximate the outlet of the second heat exchanger manifold, and opposing first and second surfaces between the leading and trailing edges, wherein the first and second surfaces are porous to provide fluidic communication between the first surface and the second surface to resist fluid separation along at least one of the first surface or the second surface.

14. The manifold for a heat exchanger as recited in claim 13, wherein the porosity of the second-manifold vane is defined by a plurality of apertures.

15. The manifold for a heat exchanger as recited in claim 13, wherein the porosity of the second-manifold vane is defined by at least one of a foam structure, slot perforations, hole perforations, and a wire mesh.

16. The manifold for a heat exchanger as recited in claim 11, further comprising additional second-manifold vanes positioned between the inlet and the outlet of the second heat exchanger manifold, wherein the second-manifold vane is a first second-manifold vane.

17. The manifold for a heat exchanger as recited in claim 16, wherein the additional second-manifold vanes each include a leading edge proximate the outlet of the heat exchanger core and a trailing edge proximate the outlet of the second heat exchanger manifold, and opposing first and second surfaces between the leading and trailing edges, wherein the first and second surfaces are porous to provide fluidic communication between the first surface and the second surface to resist fluid separation along at least one of the first surface or the second surface.

18. The manifold for a heat exchanger as recited in claim 16, wherein the porosity of each of the additional second-manifold vanes is defined by at least one of a plurality of apertures, a foam structure, slot perforations, hole perforations, and a wire mesh.

19. A method of manufacturing a vane for a heat exchanger, the method comprising:

forming a vane body having a leading edge and a trailing edge with a first surface and an opposing second surface between the leading and trailing edges, wherein the first and second surfaces are porous to provide fluidic communication between the first surface and the second surface.

20. The method of claim **19**, wherein the forming is via additive manufacturing.

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