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(54) **HEAT EXCHANGERS**

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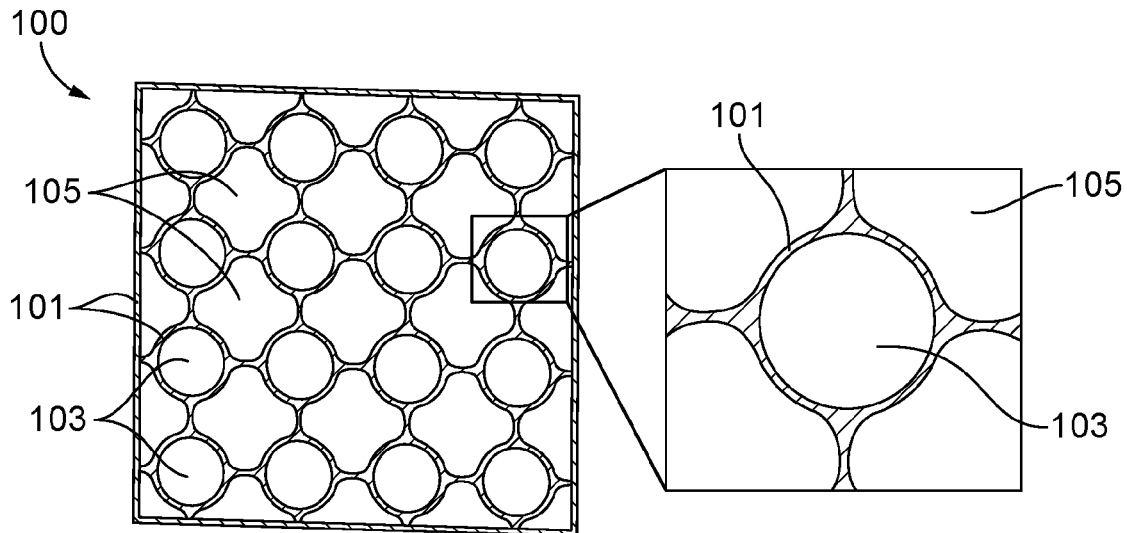
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(57) **ABSTRACT**

A heat exchanger includes a body and a plurality of elliptical flow channels defined in the body, the elliptical flow channels defining an elliptical cross-sectional flow area, and a plurality of non-elliptical flow channels defined in the body and interspersed between the elliptical flow channels, the non-elliptical flow channels having a non-elliptical cross-sectional flow area.



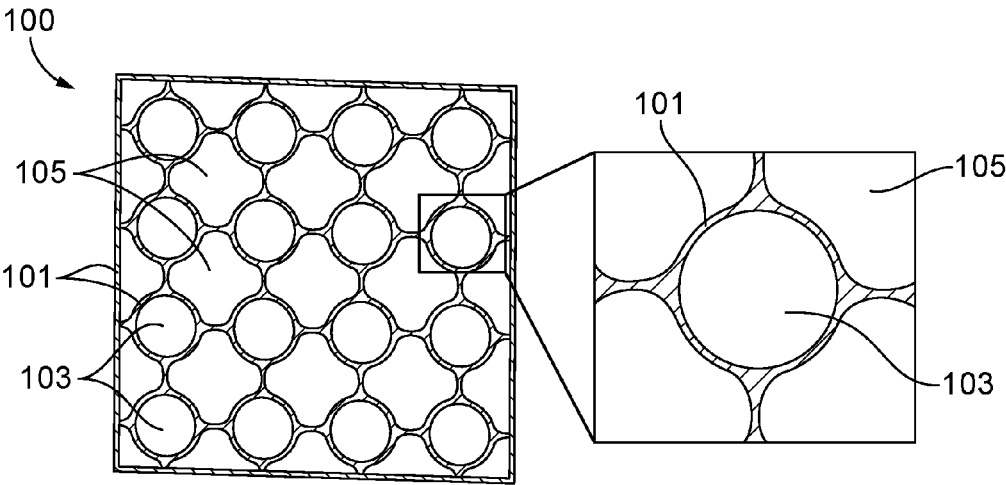


FIG. 1

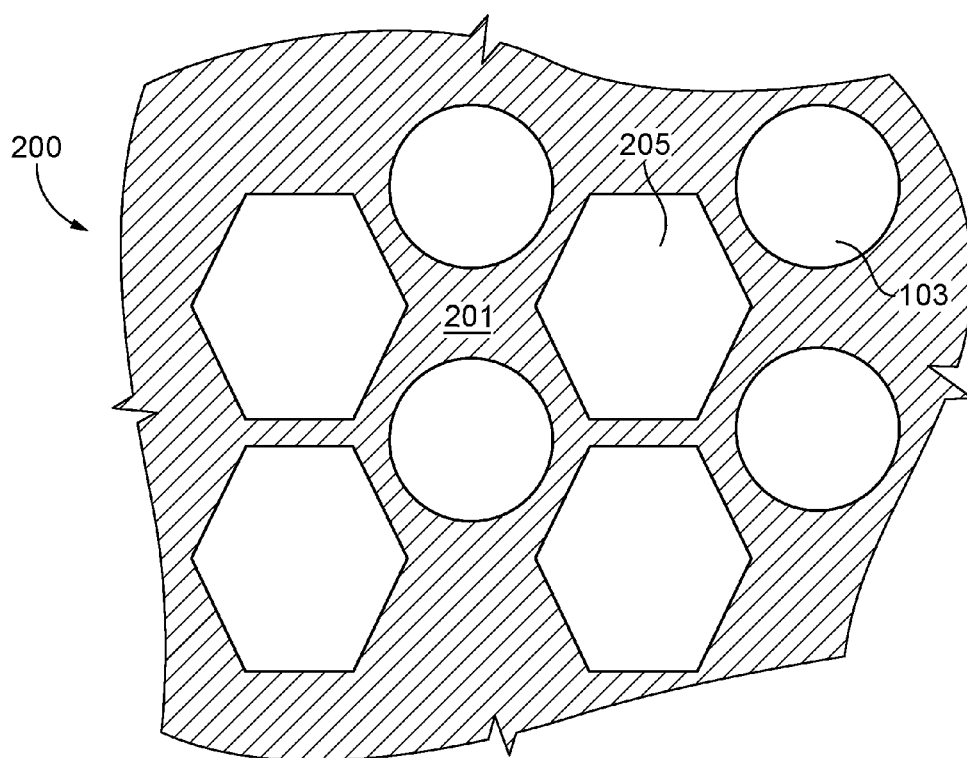


FIG. 2

HEAT EXCHANGERS

BACKGROUND

[0001] 1. Field

[0002] The present disclosure relates to heat exchangers, more specifically to more thermally efficient heat exchangers.

[0003] 2. Description of Related Art

[0004] Heat exchangers can be critical to the functionality of numerous systems (e.g., aircraft systems, engines, environmental control systems). Traditional heat exchangers include a plate fin construction, with tube shell and plate-type heat exchangers having niche applications. Traditional plate fin designs impose multiple design constraints that inhibit performance, increase size and weight, suffer structural reliability issues, are unable to meet certain high temperature applications, and limit system integration opportunities.

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

SUMMARY

[0006] A heat exchanger includes a body and a plurality of elliptical flow channels defined in the body, the elliptical flow channels defining an elliptical cross-sectional flow area, and a plurality of non-elliptical flow channels defined in the body and interspersed between the elliptical flow channels, the non-elliptical flow channels having a non-elliptical cross-sectional flow area.

[0007] At least one of the plurality of elliptical flow channels can include a circular cross-sectional flow area. At least one of the plurality of non-elliptical flow channels can include a cross-shaped or rounded-cross shaped cross-sectional flow area.

[0008] In certain embodiments, at least one of the plurality of non-elliptical flow channels can include a rectilinear shaped cross-sectional flow area. For example, the rectilinear shaped cross-sectional area can include a hexagonal shape.

[0009] The elliptical flow channels and the non-elliptical flow channels can be uniformly defined in the body such that the elliptical flow channels and non-elliptical flow channels form an evenly spaced pattern. Any other suitable pattern is contemplated herein.

[0010] In certain embodiments, the elliptical flow channels can be configured to allow a hot flow to travel through the body in a first direction. The non-elliptical flow channels can be configured to allow a cold flow to travel through the body in a second direction. In certain embodiments, the first and second directions are opposite.

[0011] A method of exchanging heat from a hot flow to a cold flow includes flowing the hot flow through a plurality of elliptical flow channels defined in a body of a heat exchanger, the elliptical flow channels defining an elliptical cross-sectional flow area, and flowing the cold flow through a plurality of non-elliptical flow channels defined in the body and interspersed between the elliptical flow channels, the non-elliptical flow channels having a non-elliptical cross-sectional flow area. In certain embodiments, flowing the hot flow through the elliptical channels can include

flowing the hot flow in a first direction, wherein flowing the cold flow through the non-elliptical channels can include flowing the cold flow in a second direction, and the first direction and second direction can be opposite.

[0012] These and other features of the systems and methods of the subject disclosure will become more readily apparent to those skilled in the art from the following detailed description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] So that those skilled in the art to which the subject disclosure appertains will readily understand how to make and use the devices and methods of the subject disclosure without undue experimentation, embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

[0014] FIG. 1 is a cross-sectional view of an embodiment of a heat exchanger in accordance with this disclosure; and

[0015] FIG. 2 is a partial cross-sectional view of another embodiment of a heat exchange in accordance with this disclosure.

DETAILED DESCRIPTION

[0016] Reference will now be made to the drawings wherein like reference numerals identify similar structural features or aspects of the subject disclosure. For purposes of explanation and illustration, and not limitation, an illustrative view of an embodiment of a heat exchanger in accordance with the disclosure is shown in FIG. 1 and is designated generally by reference character 100. Other embodiments and/or aspects of this disclosure are shown in FIG. 2. The systems and methods described herein can be used to reduce weight and/or increase performance of heat transfer systems.

[0017] Referring to FIG. 1, a heat exchanger 100 includes a body 101 and a plurality of elliptical flow channels 103 defined in the body 101. The elliptical flow channels 103 define an elliptical cross-sectional flow area. The heat exchanger 100 includes a plurality of non-elliptical flow channels 105 defined in the body 101. As shown, the non-elliptical flow channels 105 are interspersed between the elliptical flow channels 103 and define a non-elliptical cross-sectional flow area.

[0018] At least one of the plurality of elliptical flow channels 103 can include a circular cross-sectional flow area. As shown, each elliptical flow channel 103 can be circular throughout the heat exchanger 100, however, it is contemplated that the cross-sectional shape and/or size can vary from channel to channel, as a function of width, and/or along one or more flow directions. For example, the diameter /shape of elliptical flow channel 103 and/or the size/shape of the non-elliptical flow channel 105 can become smaller along a flow direction. Any other suitable variance of the elliptical flow channels 103 is contemplated herein.

[0019] As shown in the embodiment of FIG. 1, at least one of the plurality of non-elliptical flow channels 105 can include a cross-shaped or rounded-cross shaped cross-sectional flow area. Such shapes can reduce the amount of material that forms the body 101 and improve thermal transfer efficiency by increasing primary heat transfer surface area (e.g., the surfaces where heat transfers through the thickness of the material of the body 101) and decreasing secondary heat transfer surface area (surfaces where heat

must travel along a length of material of the body **101**). For example, as shown, the free form rounded-cross shape can be utilized to maintain a constant wall thickness throughout the heat exchanger **100**.

[0020] Referring to FIG. 2, in certain embodiments, at least one of the plurality of non-elliptical flow channels **205** of heat exchanger **200** can be defined by the body **201** to include a rectilinear shaped cross-sectional flow area. For example, the rectilinear shaped cross-sectional flow area can include a hexagonal shape.

[0021] Referring again to FIG. 1, the elliptical flow channels **103** and the non-elliptical flow channels **105** can be uniformly defined in the body **101** such that the elliptical flow channels **103** and non-elliptical flow channels **105** form an evenly spaced pattern (e.g., as in a checkerboard). Any other suitable pattern is contemplated herein.

[0022] In certain embodiments, the elliptical flow channels **105** can be configured to allow a hot flow to travel through the body **101** in a first direction. For example, the elliptical flow channels **103** can converge at one or more ends of the heat exchanger **100** to form a header to receive a hot flow (e.g., a hot coolant). Similarly, the non-elliptical flow channels **105** can be configured to allow a cold flow to travel through the body **101** in a second direction. In certain embodiments, the first and second directions can be opposite each other to provide a counter flow, however, the same flow direction for hot and cold flow is contemplated herein.

[0023] In certain embodiments, the heat exchanger can be monolithically formed using additive manufacturing. It is contemplated that embodiments of the heat exchanger **100** can be manufactured in any other suitable manner (e.g., casting, milling). The heat exchanger **100** can include the structure as shown as at least part of a core of the heat exchanger **100**, with any suitable header attached thereto or formed thereon.

[0024] In accordance with at least one aspect of this disclosure, a method of exchanging heat from a hot flow to a cold flow can include flowing the hot flow through a plurality of elliptical flow channels **103** as described above. The method also includes flowing the cold flow through a plurality of non-elliptical flow channels as described above. In certain embodiments, flowing the hot flow through the elliptical channels can include flowing the hot flow in a first direction, and flowing the cold flow through the non-elliptical channels can include flowing the cold flow in a second direction. As described above, the first direction and second direction can be opposite.

[0025] Embodiments described above allow maximization of primary surface area for heat exchange while allowing flexibility to increase or decrease the ratio of hot side to cold side flow area. Changing the relative amount of flow area on each side of the heat exchanger can allow full utilization of a pressure drop available on each side. For example, the procedure by which the relative amount of flow area on each side is changed can involve changing the channel dimensions along the flow direction of the channels.

[0026] Further, when high pressures are present, the shape of the channels can be critical to achieving a low stress structure with a low mass (e.g., small wall thickness). Ellipses (e.g., circles) are particularly well suited to contain high pressures of hot side flow since such shapes eliminate or reduce bending moments on the body **101**. However, using elliptical channels (e.g., circles) for both the high and low pressure side is unnecessary and results in significant

wasted space due to packing inefficiency resulting in larger and heavier heat exchangers. As described above, combining elliptical (e.g., circular) channels **103** for the high pressure (e.g., hot side) flow with non-elliptical (e.g., polygonal/rectilinear/freeform) channels **105** for the lower pressure flow (e.g., in a checkerboard like pattern) can result in more efficient space utilization and reduction of material.

[0027] Embodiments utilizing counter flow (e.g., as opposed to cross flow or) can provide improved performance by enabling improved balancing of the hot and cold side heat transfer and pressure drop, as well as increasing the heat exchanger effectiveness for a given overall heat transfer area. Counter flow can reduce the temperature differential across the heat exchanger planform since the cold side outlet is aligned with the hot side inlet, and vice versa.

[0028] Embodiments of this disclosure also have significant structural benefits that enable higher temperature and higher pressure operation over traditional devices. For example, embodiments as described above can allow heat transfer area and structural support to inlet and outlet headers. The above described features can be used to address transient thermal stress issues since the temperature response of the header and the core can be matched more closely than in a traditional open header.

[0029] The methods and systems of the present disclosure, as described above and shown in the drawings, provide for heat exchangers with superior properties including reduced weight and/or increased efficiency. While the apparatus and methods of the subject disclosure have been shown and described with reference to embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the spirit and scope of the subject disclosure.

What is claimed is:

1. A heat exchanger, comprising:
 - a body; and
 - a plurality of elliptical flow channels defined in the body, the elliptical flow channels defining an elliptical cross-sectional flow area; and
 - a plurality of non-elliptical flow channels defined in the body and interspersed between the elliptical flow channels, the non-elliptical flow channels having a non-elliptical cross-sectional flow area.
2. The heat exchanger of claim 1, wherein at least one of the plurality of elliptical flow channels includes a circular cross-sectional flow area.
3. The heat exchanger of claim 1, wherein at least one of the plurality of non-elliptical flow channels includes a cross-shaped or rounded-cross shaped cross-sectional flow area.
4. The heat exchanger of claim 1, wherein at least one of the plurality of non-elliptical flow channels includes a rectilinear shaped cross-sectional flow area.
5. The heat exchanger of claim 4, wherein the rectilinear shaped cross-sectional area includes a hexagonal shape.
6. The heat exchanger of claim 1, wherein the elliptical flow channels and the non-elliptical flow channels are uniformly defined in the body such that the elliptical flow channels and non-elliptical flow channels form an evenly spaced pattern.
7. The heat exchanger of claim 1, wherein the elliptical flow channels are configured allow a hot flow to travel through the body in a first direction.

8. The heat exchanger of claim **7**, wherein the non-elliptical flow channels are configured to allow a cold flow to travel through the body in a second direction.

9. The heat exchanger of claim **8**, wherein the first and second directions are opposite.

10. A method of exchanging heat from a hot flow to a cold flow, comprising:

flowing the hot flow through a plurality of elliptical flow channels defined in a body of a heat exchanger, the elliptical flow channels defining an elliptical cross-sectional flow area; and

flowing the cold flow through a plurality of non-elliptical flow channels defined in the body and interspersed between the elliptical flow channels, the non-elliptical flow channels having a non-elliptical cross-sectional flow area.

11. The method of claim **10**, wherein flowing the hot flow through the elliptical channels includes flowing the hot flow in a first direction, wherein flowing the cold flow through the non-elliptical channels includes flowing the cold flow in a second direction, wherein the first direction and second direction are opposite.

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