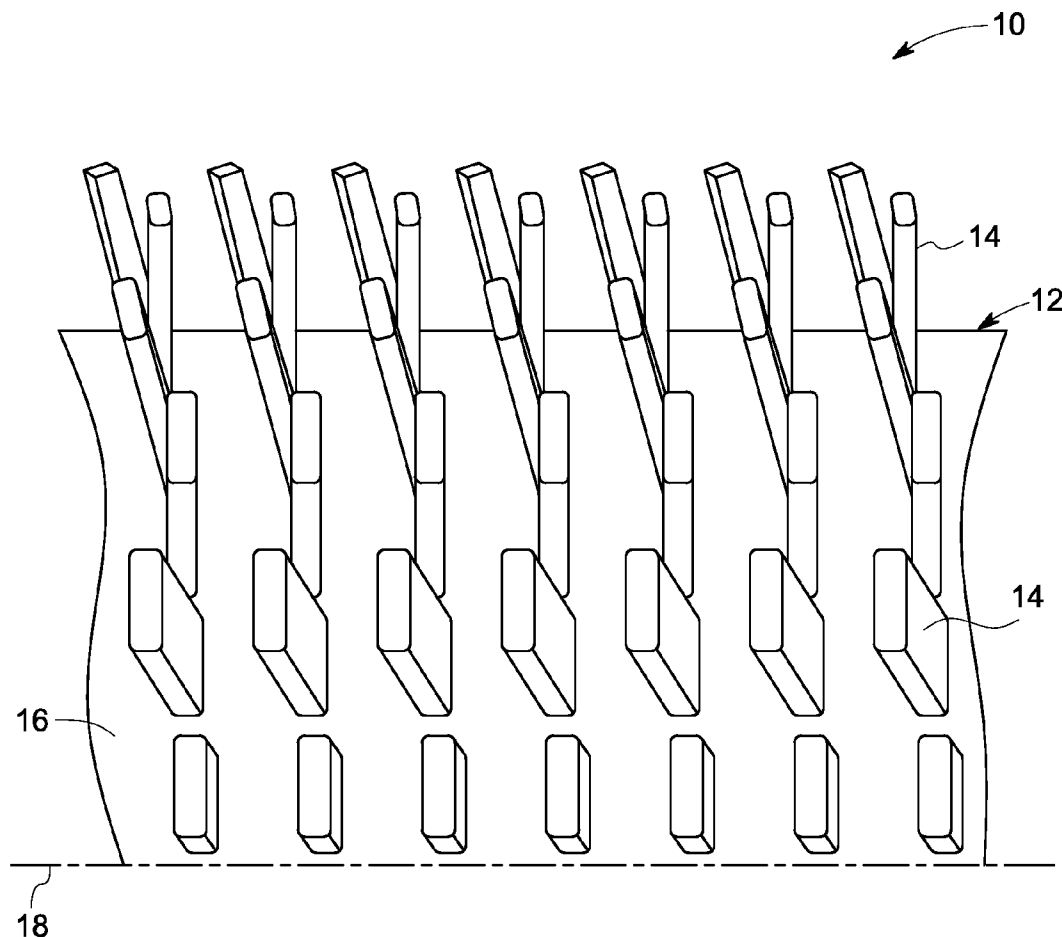


(43) **Pub. Date:** **Nov. 11, 2010**

A heat exchanger comprises a tube and fins extending from an outer surface of the tube. The fins comprise first and second sets of fins with the first set of fins oriented in a first direction with respect to an axial direction of the tube and the second set of fins oriented in a second direction with respect to the axial direction of the tube to expose at least a portion of the first and second sets of fins to a free stream.



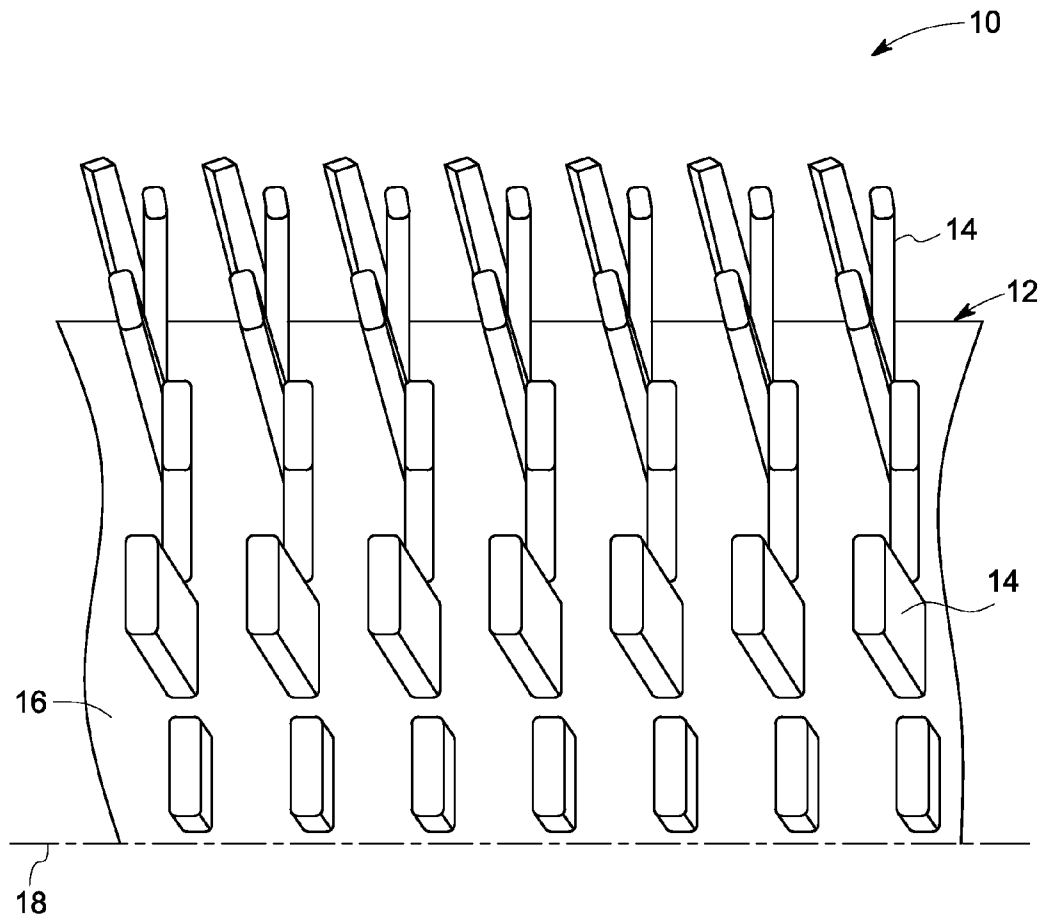


FIG. 1

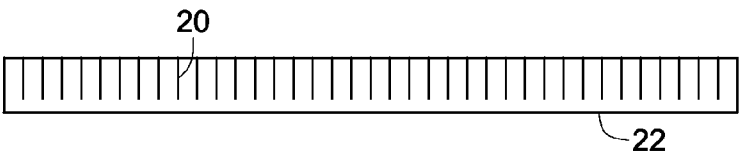


FIG. 2

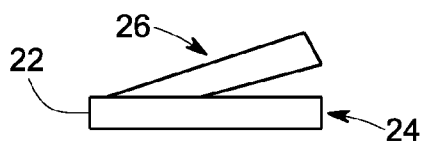


FIG. 3

10

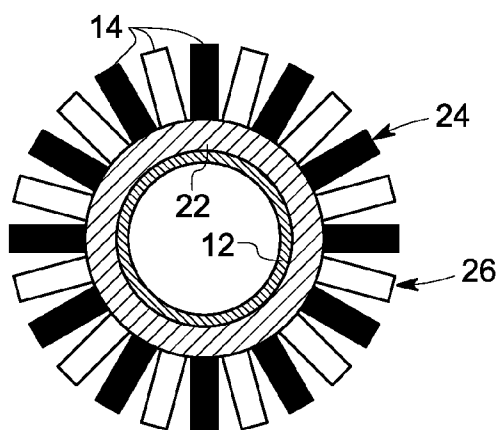


FIG. 4

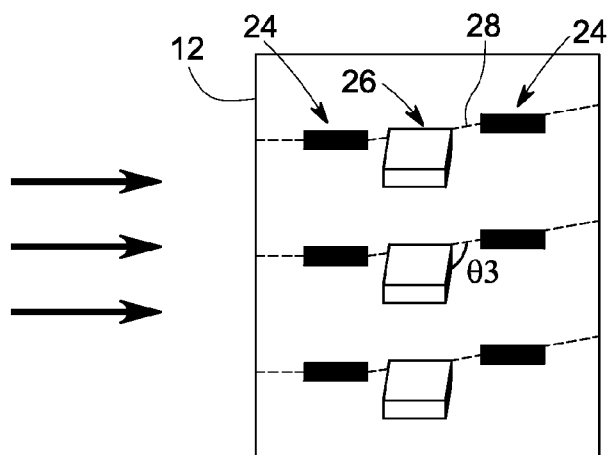


FIG. 5

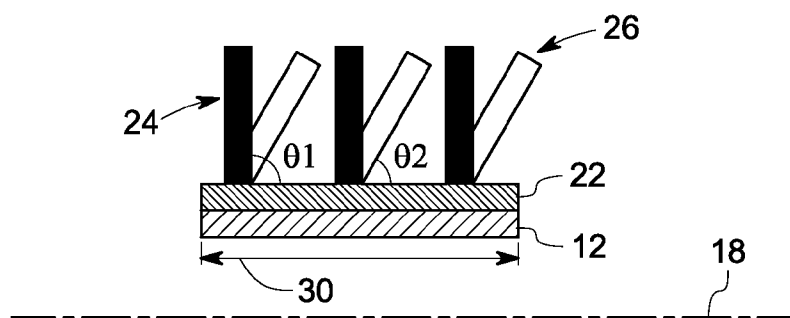


FIG. 6

32

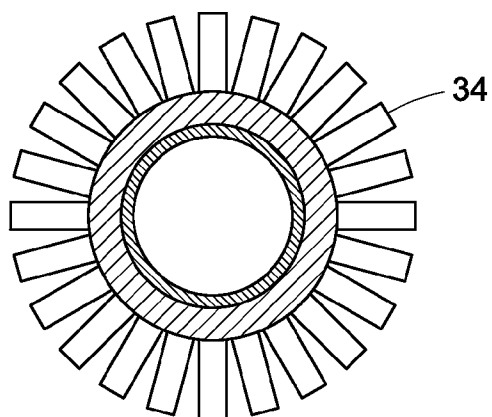


FIG. 7
(PRIOR ART)

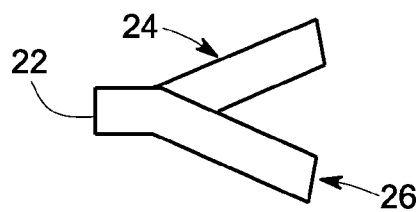


FIG. 8

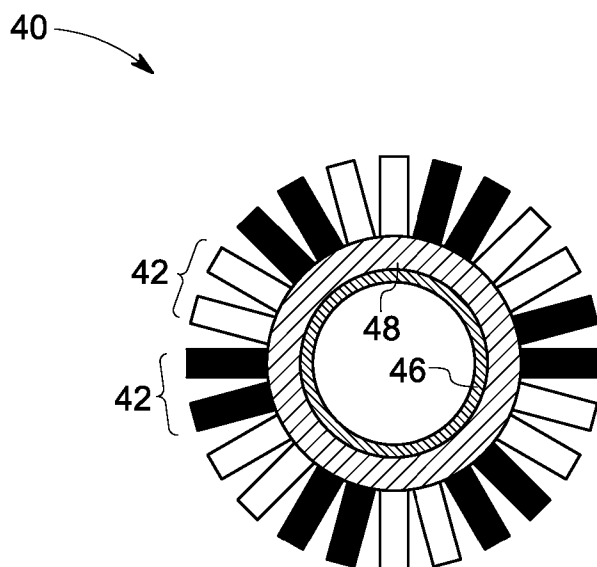


FIG. 9

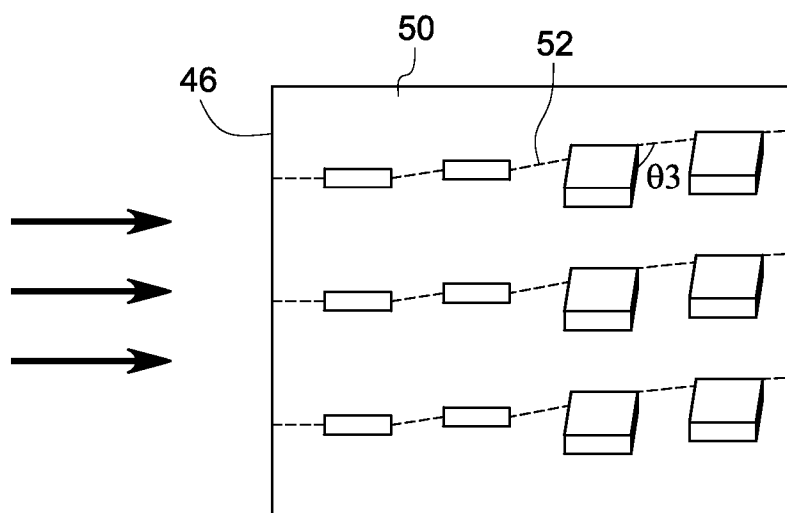


FIG. 10

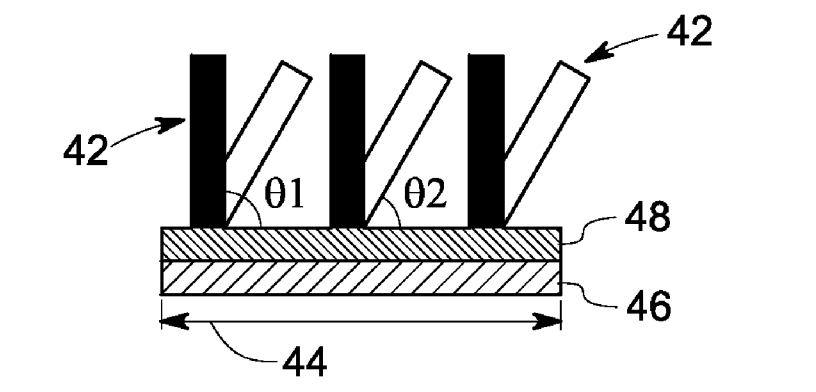


FIG. 11

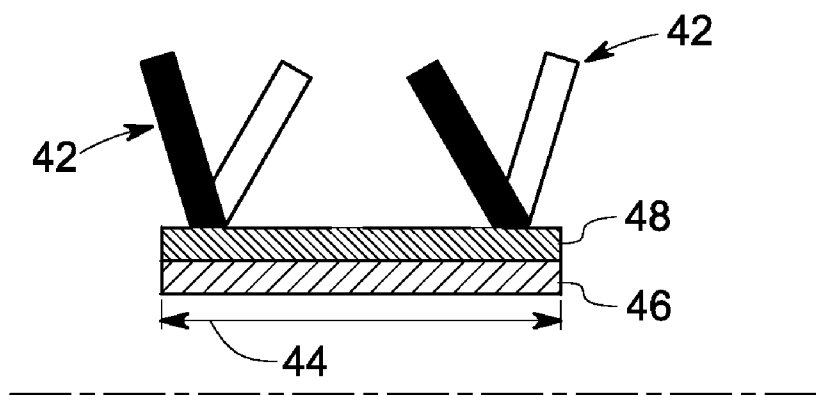


FIG. 12

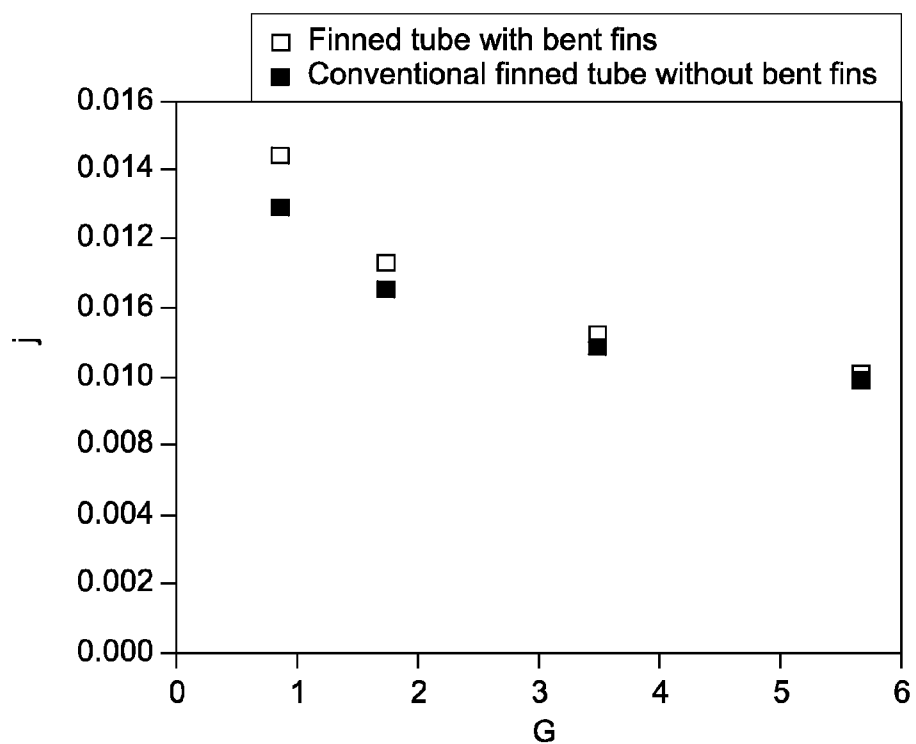


FIG. 13

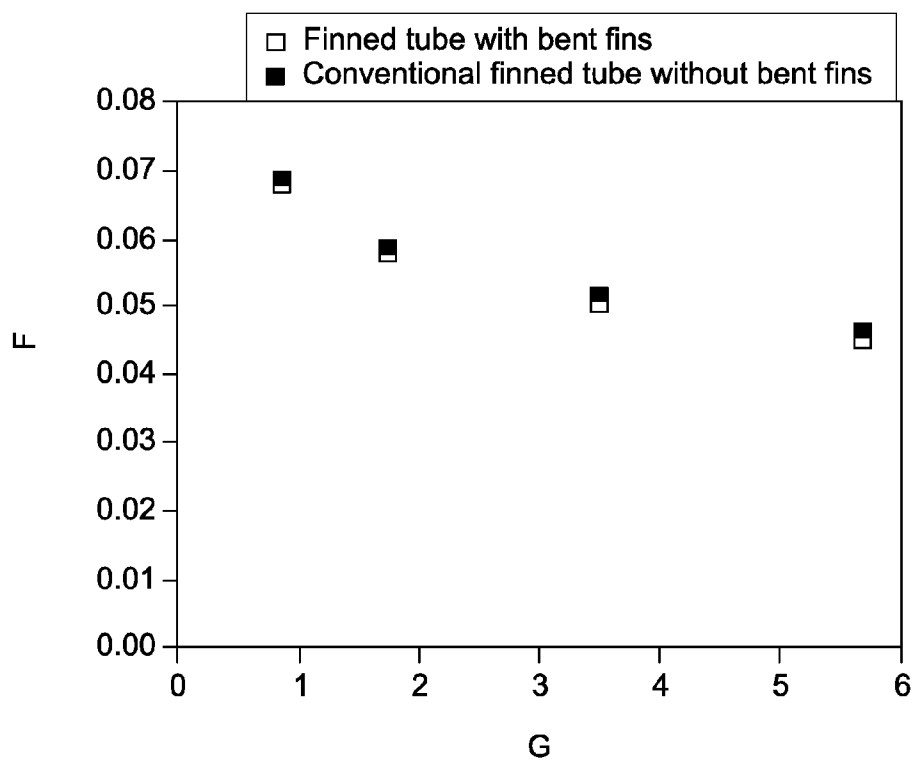


FIG. 14

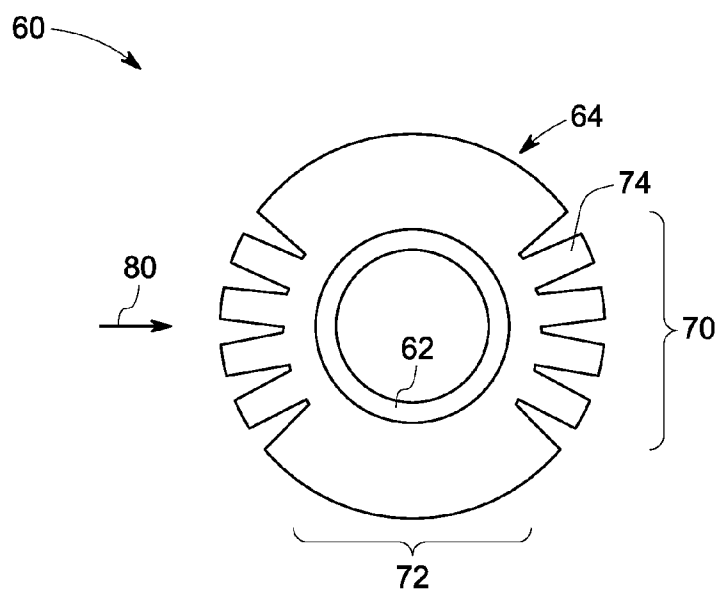


FIG. 15

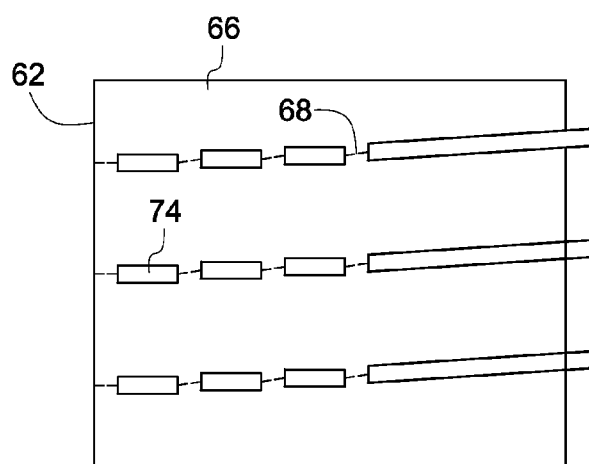


FIG. 16

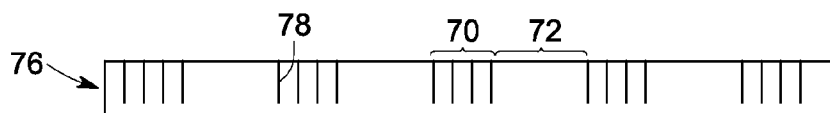


FIG. 17

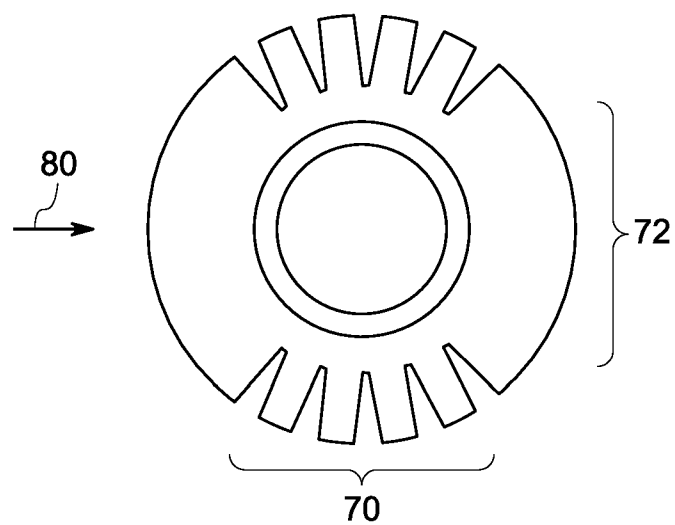


FIG. 18

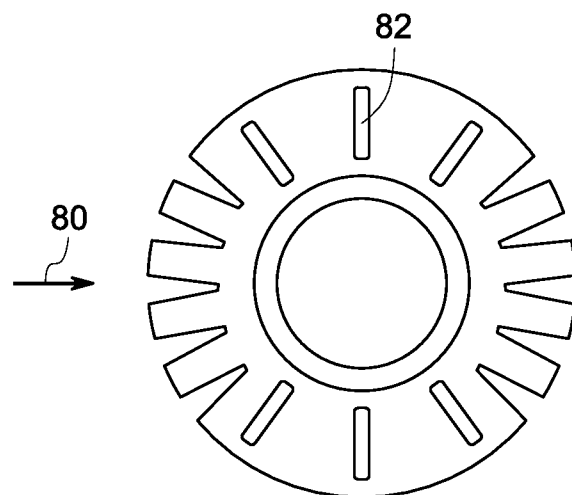


FIG. 19

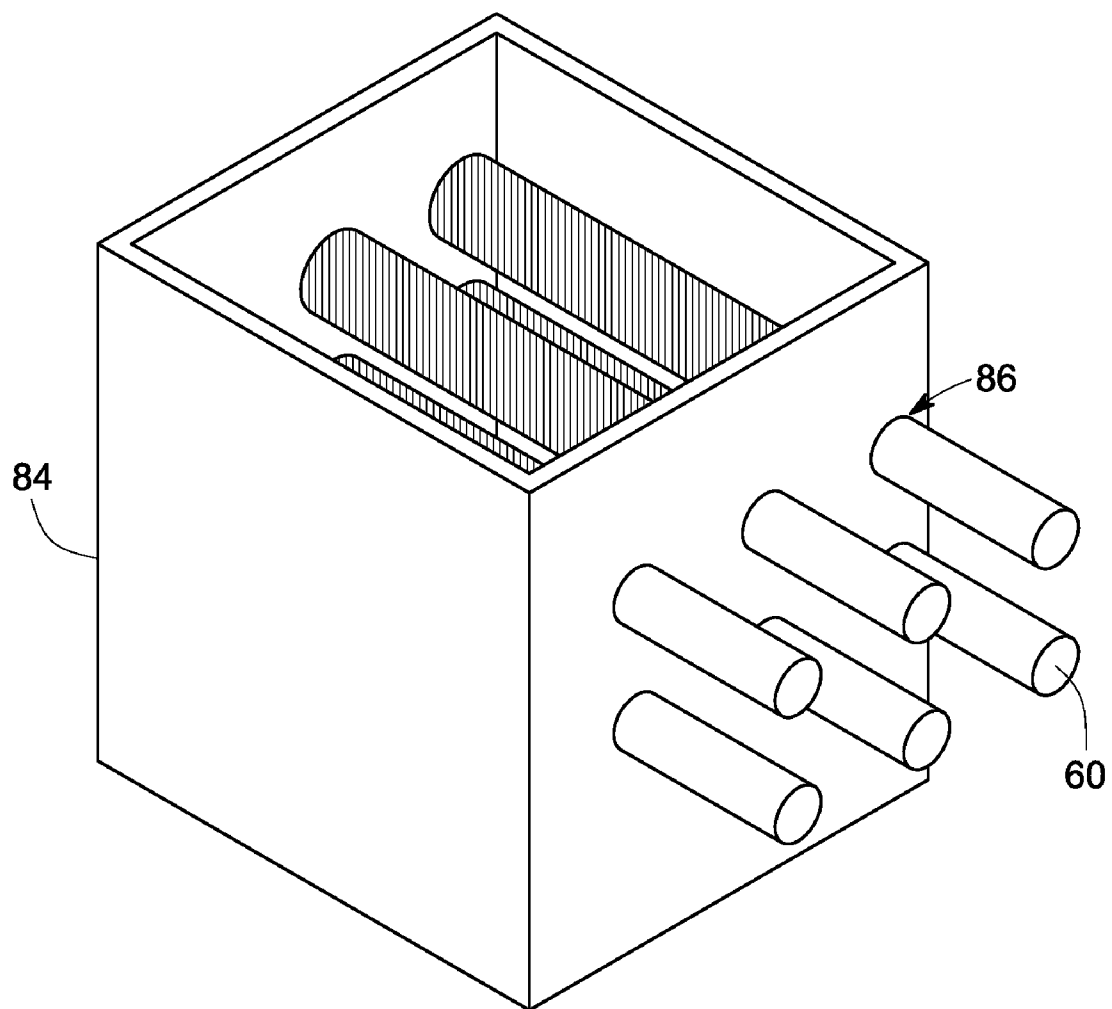


FIG. 20

FINNED TUBE HEAT EXCHANGER

BACKGROUND

[0001] The invention relates generally to heat exchangers and, more particularly, to a finned tube heat exchanger.

[0002] A finned tube heat exchanger includes a tube and fins disposed on the outer surface of the tube. Several designs for the fins are known in the art, including a serrated fin configuration. A serrated fin configuration can be formed on a tube by creating serrations in a sheet of metal and then winding the serrated sheet around the tube.

[0003] Fins including serrations, slits, and bending aspects are known in the art. Kimura (EP 0854344 A2) discloses a heat exchanger having finned tubes. The finned tubes are fabricated by attaching fins having the shape of a circular plate to the outer surface of the tube. Each fin is provided with bent portions that are formed by forming radial slits in a peripheral portion of the fin to divide the peripheral portion into a plurality of segments and then bending each segment in an axial direction of the tube along a bending line extending from a point on the radial slit. The bent portions can be formed in the same direction or in alternately opposite directions. The bent portions or tips accomplish increased flow mixing. The resultant bent tips are basically vortex generators. The goal of a vortex generator is to generate a vortex that brings higher energy particles from a free stream to low energy particles. The vortex generators reenergize boundary layers and prevent flow separation with slow recirculation. Therefore, the bent portions affect the flow and prevent or lessen the flow separation, but do not act as prime heat transfer surfaces. As a result, the heat transfer capability is compromised.

[0004] Shigenaka (U.S. Pat. No. 5,617,916) discloses a fin tube heat exchanger formed by winding a serrated fin strip around a tube. The fins are twisted at a twist angle with respect to a contact line along the base portion of the fin strip which is in contact with the tube. The fins are also inclined at an inclination angle with respect to a straight line perpendicular to an axis of the tube. This design of heat exchanger increases flow mixing. Increased flow mixing leads to higher heat transfer. However, increased flow mixing also leads to increased pressure losses. All the fins have the same level of inclination and twist angles. Therefore, an upstream fin will shade a downstream one that will only see a low speed recirculation. This twisting and inclination may increase heat transfer due to increased mixing, but the effect may become detrimental after some point. There may be increased pressure losses since the flow will most likely separate.

[0005] In order to reduce the costs, it is desirable to increase the heat transfer performance of finned tubes. An increase in heat transfer is normally associated with an increase of the pressure drop in the system. Typically, increased heat transfer can be achieved by increasing the turbulence of the flow or the effective heat transfer area. It is possible to achieve a higher heat transfer by increasing the turbulence levels of the flow, but this increase is normally penalized by an increase in the pressure drop of the heat exchanger. Serrated fins are used to generate turbulence in the flow in order to increase the heat transfer performance of the heat exchanger. However, serrated fins generate increased pressure drops compared to a simple solid fin and have less material and area for heat transfer.

[0006] It would therefore be desirable to provide finned tube heat exchangers having augmented heat transfer capability without unfavorable pressure drops.

BRIEF DESCRIPTION

[0007] In accordance with one embodiment disclosed herein, a heat exchanger comprises a tube and fins extending from an outer surface of the tube. The fins comprise first and second sets of fins with the first set of fins oriented in a first direction with respect to an axial direction of the tube and the second set of fins oriented in a second direction with respect to the axial direction of the tube to expose at least a portion of the first and second sets of fins to a free stream.

[0008] In accordance with another embodiment disclosed herein, a heat exchanger comprises a tube and fins extending from an outer surface of the tube. The fins comprise groups of contiguous fins that are oriented alternately in first and second directions with respect to an axial direction of the tube to expose the groups of contiguous fins to a free stream.

[0009] In accordance with another embodiment disclosed herein, a heat exchanger comprises a tube and fins extending from an outer surface of the tube in a helical path. The fins comprise serrated sections and solid sections that are disposed in a predetermined arrangement along the helical path.

[0010] In accordance with another embodiment disclosed herein, a heat exchanger comprises a tube and fins extending from an outer surface of the tube in a helical path. The fins comprise serrated sections and solid sections that are alternately disposed along the helical path. A portion of either the serrated sections or the solid sections are directly in the path of a free stream.

DRAWINGS

[0011] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0012] FIG. 1 illustrates a partial perspective view of an embodiment of the finned tube heat exchanger in accordance with aspects disclosed herein.

[0013] FIG. 2 illustrates a plan view of a fin strip in accordance with aspects disclosed herein.

[0014] FIG. 3 illustrates a side view of the fin strip where only alternate fins are bent with respect to the fin strip in accordance with aspects disclosed herein.

[0015] FIG. 4 illustrates a side plan view of the finned tube heat exchanger in accordance with aspects disclosed herein.

[0016] FIG. 5 illustrates a front plan view of the finned tube heat exchanger in accordance with aspects disclosed herein, wherein only few fins are depicted for clarity.

[0017] FIG. 6 illustrates a partial sectional view of the finned tube heat exchanger in accordance with aspects disclosed herein.

[0018] FIG. 7 illustrates a plan view of a standard serrated finned tube from one end.

[0019] FIG. 8 illustrates a side view of fin strip where alternate fins are bent in opposite directions with respect to the fin strip in accordance with aspects disclosed herein.

[0020] FIG. 9 illustrates a side plan view of another embodiment of the finned tube heat exchanger in accordance with aspects disclosed herein.

[0021] FIG. 10 illustrates a front plan view of the finned tube of FIG. 9 in accordance with aspects disclosed herein, wherein only few fins are depicted for clarity.

[0022] FIG. 11 illustrates a partial sectional view of the finned tube of FIG. 9 in accordance with aspects disclosed herein.

[0023] FIG. 12 illustrates a partial sectional view of another embodiment of the finned tube in accordance with aspects disclosed herein.

[0024] FIG. 13 illustrates a graph comparing Colburn factors of the finned tube heat exchanger with bent fins and a conventional serrated finned tube heat exchanger without bent fins.

[0025] FIG. 14 illustrates a graph comparing friction factors of the finned tube heat exchanger with bent fins and a conventional serrated finned tube heat exchanger without bent fins.

[0026] FIG. 15 illustrates a side plan view of another embodiment of the finned tube heat exchanger with serrated sections directly in the path of a free stream in accordance with aspects disclosed herein.

[0027] FIG. 16 illustrates a front plan view of the finned tube heat exchanger of FIG. 15 in accordance with aspects disclosed herein.

[0028] FIG. 17 illustrates a plan view of a fin strip with slits formed only in selected locations in accordance with aspects disclosed herein.

[0029] FIG. 18 illustrates a side plan view of the finned tube heat exchanger with solid sections in the path of a free stream in accordance with aspects disclosed herein.

[0030] FIG. 19 illustrates a side plan view of another embodiment of the finned tube heat exchanger with heat transfer enhancing features in accordance with aspects disclosed herein.

[0031] FIG. 20 illustrates a frame for housing finned tubes in accordance with aspects disclosed herein.

DETAILED DESCRIPTION

[0032] Embodiments disclosed herein include serrated finned tube heat exchangers. The finned tube heat exchanger includes a tube and fins extending from the outer surface of the tube. The fins are arranged and designed in a manner to augment heat transfer capability and reduce or minimize pressure drops compared to a standard serrated finned tube heat exchanger. In one embodiment, the fins include serrated fins that are disposed along a helical path corresponding to first and second directions with respect to an axial direction of the tube. In another embodiment, the fins include serrated and solid sections that are disposed in a predetermined arrangement along a helical path. As used herein, singular forms such as “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise.

[0033] Referring to FIGS. 1-3, an embodiment of the finned tube heat exchanger 10 includes a tube 12 and a plurality of fins 14 extending from an outer surface 16 of the tube 12. The tube 12 has a length along an axis 18 passing through the center of the tube 12. The fins 14 are disposed around the outer surface 16 of the tube 12 in a generally helical configuration. The fins 14 can be formed by first creating slits 20 on a fin strip 22. The fin strip 22 is then helically wound and attached on the outer surface 16 of the tube 12. In one embodiment, every alternate fin 14 is bent with respect to the fin strip 20. A first set of fins 24 includes unbent fins and a second set of fins 26 includes bent fins. The second set of fins 26 can be

bent in any angle ranging from -90 degrees to $+90$ degrees with respect to the plane of the fin strip 22.

[0034] FIGS. 4-6 illustrate various views of the finned tube heat exchanger 10. Fins in the first set of fins 24 are shown as shaded to differentiate from the second set of fins 26. The fin strip 22 is positioned in a helical path 28 around the tube 12. The first set of fins 24 are oriented in a first direction ‘ $\theta 1$ ’ with respect to the axial direction 30 of the tube 12. The axial direction 30 of the tube is along the axis 18 of the tube 12. The second set of fins 26 are oriented in a second direction ‘ $\theta 2$ ’ with respect to the axial direction 30. Since only the second set of fins 26 is bent, the first set of fins 24 are in line with the helical path 28 and the second set of fins 26 are positioned at an angle ‘ $\theta 3$ ’ with respect to the helical path 28. Fins in the second set of fins 26 are therefore out of the plane of the helical fin strip 22. In a standard serrated fin 32 as shown in FIG. 7, all the fins 34 have the same orientation with respect to each other and the fins 34 would generally be in line with a helical path, i.e. $\theta 1 = \theta 2$ and $\theta 3 = 0$.

[0035] In another embodiment as shown in FIG. 8, alternate fins are bent in opposite directions with respect to the fin strip 22. For example, the first set of fins 24 can be bent in any angle ranging from 0 degrees to $+90$ degrees with respect to the plane of the fin strip 22 and the second set of fins 26 can be bent in any angle ranging from -90 degrees to 0 degrees with respect to the plane of the fin strip 22. In this case, both the first set of fins 24 and the second set of fins 26 will be at an angle with respect to the helical path after the fin strip 22 is helically wound around the tube.

[0036] The arrangement of the first and second set of fins 24 and 26 results in a configuration where every fin is oriented differently with respect to a contiguous fin along the helical path 28. Each fin is therefore exposed to a free stream of air (denoted by arrows in FIG. 5) flowing towards the tube 12. A free stream air is at a higher temperature and therefore there is more potential for heat transfer. The boundary layer formed at the surface of each fin 14 is one of the leading obstacles to better heat transfer. The second set of fins 26 (bent fins) will shed vortices, increasing the mixing of a downstream flow and enhancing mixing and disrupting of boundary layers. Being out of plane, the second set of fins 26 will not be significantly affected by any boundary layer from an upstream fin. This will reduce the local thermal resistance, thereby enhancing heat transfer capability.

[0037] Also, the distance a flow travels after an unbent upstream fin 24 and until an unbent downstream fin 24 is longer compared to a conventional serrated fin, since the bent fin 26 does not block the flow between an unbent upstream fin 24 and an unbent downstream fin 24. The increased distance allows for wake dissipation and increased speed at the leading edge of a downstream fin. Any remaining wake is eliminated on impact with a downstream fin. The different orientations of first sets of fins 24 (unbent fins) and second set of fins 26 (bent fins) results in a flow condition that is closer to a three dimensional flow field than a two dimensional flow. In a conventional serrated configuration, in which fins 26 are not bent, the wake dissipation would be much shorter.

[0038] The finned tube heat exchanger 10 does not have unfavorable effects compared to a standard serrated finned tube from pressure or head loss perspective. Flow around the fins 14 would be in laminar and low turbulence regimes. Wall friction losses should be unchanged compared to a standard serrated finned tube because there is no increase in area of the

fins. Tip vortices generated by the fins 14 are only displaced compared to a standard serrated finned tube, without major change in magnitude.

[0039] In another embodiment 40 as shown in FIGS. 9-11, groups of contiguous fins 42 are oriented alternately in first and second directions with respect to an axial direction 44 of the tube 46. For example, pairs of contiguous fins 42 are oriented alternately in first and second directions. Fins oriented in the first direction are shown as shaded to differentiate from the fins oriented in the second direction. The first direction is at an angle 'θ1' with respect to the axial direction 44 of the tube 46 and the second direction is at an angle 'θ2' with respect to the axial direction 44 of the tube 46. This configuration can be achieved by bending every alternate pair of contiguous fins 42 before winding the fin strip 48 around an outer surface 50 of the tube 46. In another embodiment as shown in FIG. 12, pairs of alternate fins can be bent such that both the first and second directions are at an angle with respect to the helical path.

[0040] The first direction will be in line with the helical path 52 and the second direction will be at an angle 'θ3' with respect to the helical path 52. Every pair of contiguous fins 42 is therefore exposed to a free stream of air (denoted by arrows) flowing towards the tube 46. As discussed previously with respect to the embodiment of FIGS. 4-6, the finned tube heat exchanger 40 also has enhanced heat transfer capability and does not have unfavorable effects compared to a standard serrated finned tube from pressure or head loss perspective.

[0041] The bent-fin embodiments described above provide higher heat transfer coefficients compared to standard serrated fin and also solid fin tube configurations. Experimental results show about an 8 percent increase in heat transfer coefficient compared to standard serrated fins. This augmented heat transfer capability is achieved without increasing pressure losses compared to the standard serrated fin. Colburn factor (j) is used to characterize heat transfer coefficient and friction factor (f) is used to characterize pressure drop. The Colburn factor and friction factor are experimentally determined and plotted versus mass flux, G, in FIGS. 13 and 14, respectively, for the finned tube heat exchanger with bent fins and a conventional serrated finned tube heat exchanger without bent fins. The data in FIGS. 13 and 14 was obtained in a wind tunnel experiment using heated air on the finned tube side and water inside the tubes. The inlet air pressure and temperature and outlet air pressure and temperature were measured across a bundle including four rows of finned tubes arranged in a staggered pattern. From these measurements, the Colburn factor and friction factor as a function of mass flux were determined.

[0042] Referring to FIGS. 15-17, another embodiment of the finned tube heat exchanger 60 includes a tube 62 and fins 64 extending from an outer surface 66 of the tube 62 in a helical path 68. The fins 64 include serrated sections 70 and solid sections 72. The serrated sections 70 and solid sections 72 are alternately disposed along the helical path 68. The serrated sections 70 include a plurality of individual fins 74 that extend substantially until the outer surface 66 of the tube 62. The fins 64 can be formed on a fin strip 76. Slits 78 are created on the fin strip 76 corresponding to the serrated sections 70. The fin strip 76 is then helically wound and attached to the outer surface 66 of the tube 62. Portions of the fin strip 76 without the slits form the solid sections 72.

[0043] In one embodiment, a single revolution on the fin strip 76 around the tube 62 includes two serrated sections 70

and two solid sections 70 that are alternately arranged. Therefore, referring to FIG. 15, all of the serrated sections 70 on the top side of the tube 62 are in line with each other and all of the solid sections 72 on the bottom side of the tube 62 are in line with each other. Similarly, all of the serrated sections 70 on the left side of the tube 62 are in line with each other and all of the solid sections 72 on the right side of the tube 62 are in line with each other.

[0044] The combination of serrated and solid sections 70 and 72 increases turbulence of the flow, enhancing heat transfer capability, and minimizes the overall pressure drop. The solid sections increase the available heat transfer area compared to standard serrated finned tube (shown in FIG. 7) that has a plurality of individual fins. A reduced number of individual fins in the finned tube will result in lower pressure drops. The orientation of the finned tube with respect to the flow can be determined according to the flow conditions in order to provide a balance between increased heat transfer and reduced pressure drop. In the embodiment shown in FIG. 15, the finned tube 60 is positioned such that the serrated sections 70 on one side of the tube 62 are directly in the path of a free stream 80. In another embodiment as shown in FIG. 18, the finned tube 60 is positioned such that the solid sections 72 on one side of the tube 62 are directly in the path of a free stream 80. The finned tube 60 can further include heat transfer enhancing features 82 such as grooves, dimples, or corrugations on the solid sections as shown in FIG. 19.

[0045] The finned tubes 60 can be arranged in bundles as shown in FIG. 20. A frame 84 can be used to house bundles of the finned tubes 60. The frame 84 can include a mechanism 86 to mount the finned tubes 60 in a specific position such that either the solid sections on one side of the tube 60 or the serrated sections on another side of the tube 60 are directly in the path of a free stream. In one embodiment, the mechanism 86 can include a notch at the end of the tube 60 and a mating feature for the notch on the frame 84 so that the fins can be aligned appropriately with respect to the flow.

[0046] The finned tube heat exchangers thus provide a way to augment heat transfer without unfavorable pressure drops. In bent-fin embodiments, heat transfer capability can be enhanced without an increase in pressure drop compared to a standard serrated finned tube. In solid-serrated section embodiments, heat transfer capability can be enhanced and pressure drop can be reduced compared to a standard serrated finned tube.

[0047] It is to be understood that not necessarily all such objects or advantages described above may be achieved in accordance with any particular embodiment. Thus, for example, those skilled in the art will recognize that the systems and techniques described herein may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein.

[0048] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

1. A heat exchanger, comprising:
a tube; and

fins extending from an outer surface of the tube, the fins comprise first and second sets of fins with the first set of

fins oriented in a first direction with respect to an axial direction of the tube and the second set of fins oriented in a second direction with respect to the axial direction of the tube to expose at least a portion of the first and second sets of fins to a free stream.

2. The heat exchanger of claim 1, wherein the first and second sets of fins are alternately arranged to expose each of the fins to the free stream.

3. The heat exchanger of claim 1, wherein the fins are arranged in a helical path around the outer surface of the tube.

4. The heat exchanger of claim 3, wherein the first direction is in line with the helical path and the second direction is at an angle with respect to the helical path.

5. The heat exchanger of claim 3, wherein the first direction and the second direction are at an angle with respect to the helical path.

6. The heat exchanger of claim 1, wherein the fins are formed by creating slits on a fin strip and bending the first set of fins, the second set of fins, or both the first and second sets of fins with respect to the fin strip before helically winding and attaching the fin strip on the outer surface of the tube.

7. A heat exchanger, comprising:

a tube; and

fins extending from an outer surface of the tube, the fins comprise groups of contiguous fins that are oriented alternately in first and second directions with respect to an axial direction of the tube to expose the groups of contiguous fins to a free stream.

8. The heat exchanger of claim 7, wherein the fins are arranged in a helical path around the outer surface of the tube.

9. The heat exchanger of claim 8, wherein the first direction is in line with the helical path and the second direction is at an angle with respect to the helical path.

10. The heat exchanger of claim 8, wherein the first direction and the second direction are at an angle with respect to the helical path.

11. The heat exchanger of claim 7, wherein the fins are formed by creating slits on a fin strip and bending a portion of fins with respect to the fin strip to correspond to the first and second directions before helically winding and attaching the fin strip on the outer surface of the tube.

12. A heat exchanger, comprising:

a tube; and

fins extending from an outer surface of the tube in a helical path, the fins comprise serrated sections and solid sections that are disposed in a predetermined arrangement along the helical path.

13. The heat exchanger of claim 12, wherein the serrated sections and the solid sections are alternately disposed along the helical path.

14. The heat exchanger of claim 12, wherein a portion of the serrated sections are directly in the path of a free stream.

15. The heat exchanger of claim 12, wherein a portion of the solid sections are directly in the path of a free stream.

16. The heat exchanger of claim 12, wherein the solid sections comprise groove, dimples, corrugations, or other heat transfer enhancing features.

17. The heat exchanger of claim 12, wherein each of the serrated sections includes a plurality of individual fins that extend substantially till the outer surface of the tube.

18. The heat exchanger of claim 17, wherein the fins comprise a fin strip that is helically wound and attached to the outer surface of the tube, with slits created on the fin strip corresponding to the serrated sections before helically winding the fin strip.

19. A heat exchanger, comprising:

a tube; and

fins extending from an outer surface of the tube in a helical path, the fins comprise serrated sections and solid sections that are alternately disposed along the helical path, wherein the tube is positioned such that a portion of either the serrated sections or the solid sections are directly in the path of a free stream.

20. The heat exchanger of claim 19, wherein the solid sections comprise groove, dimples, corrugations, or other heat transfer enhancing features.

21. The heat exchanger of claim 19, wherein each of the serrated sections includes a plurality of individual fins that extend substantially till the outer surface of the tube.

22. The heat exchanger of claim 21, wherein the fins comprise a fin strip that is helically wound and attached to the outer surface of the tube, with slits created on the fin strip corresponding to the serrated sections before helically winding the fin strip.

* * * * *