(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 054 253 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
03.04.2019 Bulletin 2019/14

(51) Int Cl.:
F28F 1/40 *(2006.01)* ***F28F 1/42*** *(2006.01)*

(21) Application number: **16154908.4**

(22) Date of filing: **09.02.2016**

(54) **HEAT EXCHANGER ARTICLE WITH HOLLOW TUBE HAVING PLURALITY OF VANES**

WÄRMETAUSCHERARTIKEL MIT HOHLWELLENROHR MIT MEHREREN SCHAUFELN

ARTICLE D'ÉCHANGEUR DE CHALEUR À TUBE CREUX AYANT UNE PLURALITÉ D'AUBES

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **09.02.2015 US 201514616819**

(43) Date of publication of application:
10.08.2016 Bulletin 2016/32

(73) Proprietor: **United Technologies Corporation**
Farmington, CT 06032 (US)

(72) Inventors:
- **KIRONN, Lexia**
  Rocky Hill, CT Connecticut 06067 (US)
- **TWELVES, Jr., Wendell V.**
  Glastonbury, CT Connecticut 06033 (US)
- **OTT, Joe**
  Enfield, CT Connecticut 06082 (US)
- **BUTCHER, Evan**
  Manchester, CT Connecticut 06042 (US)

(74) Representative: **Dehns**
St. Brides House
10 Salisbury Square
London EC4Y 8JD (GB)

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EP 3 054 253 B1

Description

BACKGROUND

[0001] This disclosure relates to heat exchanger articles that have internal features for enhancing thermal exchange.

[0002] A heat exchanger can include one or more tubes for transferring a first working fluid. A second working fluid can be passed around the outside of the tubes such that there is a thermal exchange between the two working fluids. The tube can include pins on the inside that are used to increase surface area and thus increase heat transfer between the fluids. The tubes and pins are typically fabricated by joining several pieces together using welding or brazing techniques.

[0003] US 2011/094721 A1 discloses a heat exchanger article according to the preamble of independent claim 1.

[0004] WO 2014/125260 A1 discloses an apparatus and method of optimising fluid flow in a heat exchange system.

[0005] GB 1 359 647 A discloses heat transfer tubes having an extended surface on the inner side of the tube, in the form of a fin or strip extending helically around the tube.

SUMMARY

[0006] A heat exchanger article according to the invention includes a monolithic hollow tube including a tube wall with an interior surface and an exterior surface, the interior surface defines a flow passage through the hollow tube, and a vane cluster in the flow passage. The vane cluster includes a plurality of vanes, and each of the vanes extends inwardly from the tube wall.

[0007] In a further embodiment of any of the foregoing embodiments, the vanes of the vane cluster extend inwardly toward a common central axis of the hollow tube.

[0008] In a further embodiment of any of the foregoing embodiments, each of the vanes has a twist from a vane leading edge to a vane trailing edge.

[0009] In a further embodiment of any of the foregoing embodiments, each of the vanes has an airfoil shape.

[0010] In a further embodiment of any of the foregoing embodiments, the vanes of the vane cluster meet at a central hub.

[0011] In a further embodiment of any of the foregoing embodiments, the hollow tube includes a plurality of protrusions extending outwardly from the exterior surface.

[0012] In a further embodiment of any of the foregoing embodiments, each of the vanes has a length from a vane leading edge to a vane trailing edge and a span from a vane outer side to a vane inner side, and a ratio of the length to the span is greater than 1:1.

[0013] In a further embodiment of any of the foregoing embodiments, at least one of the vane clusters has a clockwise twist and at least one other of the vane clusters has a counter-clockwise twist.

[0014] In a further embodiment of any of the foregoing embodiments, the series of vane clusters has an alternating arrangement of vane clusters with regard to clockwise twist and counter-clockwise twist.

[0015] In a further embodiment of any of the foregoing embodiments, each of the vane clusters has a twist, and the series of vane clusters has a progressively changing twist.

[0016] In a further embodiment of any of the foregoing embodiments, each of the vane clusters has a twist, and the series of vane clusters has a progressively changing twist between clockwise twist and counter-clockwise twist.

[0017] In a further embodiment of any of the foregoing embodiments, the flow passage is unobstructed between the vane clusters.

[0018] In a further embodiment of any of the foregoing embodiments, the hollow tube is monolithic.

[0019] The heat exchanger article preferably further includes the hollow monolithic tube having first and second ends. The tube wall circumscribes the flow passage that extends from the first end to the second end, and the plurality of vanes are spaced from at least one of the first and second ends and extend inwardly from the tube wall.

[0020] In a further embodiment of any of the foregoing embodiments, each of the vanes extends inwardly toward a common central axis of the monolithic tube.

[0021] In a further embodiment of any of the foregoing embodiments, each of the vanes has a twist from a vane leading edge to a vane trailing edge.

[0022] In a further embodiment of any of the foregoing embodiments, each of the vanes has an airfoil shape.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The various features and advantages of the present disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

Figure 1 illustrates an example heat exchanger with a heat exchanger article that is a hollow tube with a plurality of internal vanes.

Figure 2 illustrates an example airfoil geometry of a vane of a hollow tube.

Figure 3 illustrates another example hollow tube that has a series of vane clusters spaced along the flow passage.

Figure 4 illustrates a hollow tube with vane clusters that have either a counterclockwise twist or a clockwise twist.

Figure 5 illustrates a hollow tube with progressively changing twist of the vane clusters.

Figure 6 illustrates a hollow tube with vane clusters that progressively change between counterclockwise and clockwise.

Figure 7 illustrates a hollow tube with an alternating arrangement of vane clusters with regard to clockwise twist and counterclockwise twist.

Figure 8 illustrates another example hollow tube that has protrusions on the exterior surface.

DETAILED DESCRIPTION

[0024] Figure 1 schematically illustrates an example heat exchanger 20 that has one or more heat exchanger articles 22. In this example, the heat exchanger article 22 is a hollow tube 24. For example, the hollow tube 24 is formed of an alloy material, such as but not limited to aluminum alloy, nickel alloy, iron alloy, or copper alloy. Typically, a working fluid is passed through the hollow tube 24 and a second working fluid is passed around the outside of the hollow tube 24 such that there is a thermal exchange between the two working fluids. As can be appreciated, this disclosure is not limited to any particular type of heat exchanger, and the examples herein can be applied to other types of heat exchangers.

[0025] Some heat exchanger tubes include internal pins that function to increase surface area for greater thermal exchange. However, manufacturing processes such as brazing and welding limit the type and geometry of internal features. In this regard, an alternative fabrication process, such as additive manufacturing, can be used to fabricate internal features that are not feasible using other manufacturing techniques.

[0026] In the illustrated example, the hollow tube 24 includes a tube wall 26 that has an interior surface 26a and an exterior surface 26b. The interior surface 26a defines a flow passage 28 through the hollow tube 24. The hollow tube 24 also includes a static vane cluster 30 in the flow passage 28. The vane cluster 30 includes a plurality of vanes 32, and each of the vanes 32 extends inwardly from the tube wall 26. For instance, the vanes 32 extend from the tube wall 26, rather than an intermediate structure.

[0027] Each of the vanes 32 includes a leading edge 34 and a trailing edge 36 that define a length dimension that is generally parallel to a central axis A of the hollow tube 24. The vanes 32 each also have a span dimension from a vane outer side 38 at the tube wall 26 to a vane inner side 40 that is spaced inwardly from the tube wall 26. In one example, the vanes 32 are longer than they are wide, and the vanes thus have a ratio of length to span that is greater than 1:1.

[0028] In this example, each of the vanes 32 also has a vane twist. That is, the body of each of the vanes 32 twists along the length direction. The twist of the vanes 32 serves to swirl working fluid that flows through the flow passage 28 over the vanes 32. Thus, the vanes 32 can have either a clockwise twist or a counterclockwise twist to cause, respectively, clockwise or counterclockwise swirl of the fluid. The swirl of the working fluid serves to promote a more uniform temperature distribution. Moreover, the vanes 32 increase surface area and, therefore, also promote heat transfer through the tube wall 26.

[0029] In this example, each of the vanes 32 extends radially inwardly toward the common central axis A of the hollow tube 24. The vanes 32 meet at a hub 42, which joins all of the vanes 32 and structurally supports the vanes 32 relative to the tube wall 26. In this example, the hub 42 is cylindrical, although the hub 42 could alternatively have a different geometry. In one modification, the hub 42 is excluded such that the vanes 32 either have free inner ides or the vanes 32 meet at a relatively smaller hub.

[0030] Additive manufacturing can be used to form the tube wall 26 and the vane cluster 30. Additive manufacturing involves building an article layer-by-layer from a powder material by consolidating selected portions of each successive layer of powder until the complete article is formed. For example, the powder is fed into a chamber, which may be under vacuum or inert cover gas. A machine deposits multiple layers of the powder onto one another. An energy beam, such as a laser, selectively heats and consolidates each layer with reference to a computer-aided design data to form solid structures that relate to a particular cross-section of the article. Other layers or portions of layers corresponding to negative features, such as cavities or openings, are not joined and thus remain as a powdered material. The unjoined powder material may later be removed using blown air, for example. With the layers built upon one another and joined to one another cross-section by cross-section, the article, or a portion thereof, such as for a repair, is produced. The article may be post-processed to provide desired structural characteristics. For example, the article may be heat treated to produce a desired microstructure. Additive manufacturing processes can include, but are not limited to, selective laser melting, direct metal laser sintering, electron beam melting, 3D printing, laser engineered net shaping, or laser powder forming.

[0031] The additive manufacturing process can be used to form the hollow tube 24 as a monolithic tube. In this regard, the hollow tube 24 is seamless with regard to distinct boundaries that would otherwise be formed using techniques such as welding or brazing. Thus, the (monolithic) hollow tube 24, in one example, is free of seams such that there are no distinct boundaries or discontinuities in the hollow tube 24 that are visually or microscopically discernable.

[0032] Figure 2 illustrates a further example of a representative vane 132 that can be used in the hollow tube 24. In this example, the vane 132 has an airfoil shape 150. An airfoil shape is a geometry that provides a reaction force as fluid flows over the airfoil. Although the vanes 132 are static in the hollow tube 24, the airfoil shape can facilitate the reduction of friction.

[0033] Figure 3 illustrates another example hollow tube 124. In this disclosure, like reference numerals designate like elements where appropriate and reference numerals with the addition of one-hundred are multiples thereof designate modified elements that are understood to incorporate the same features and benefits of the corresponding elements. In this example, the hollow tube 124 includes a series 144 of the vane clusters 30 spaced apart in the flow passage 28. Each of the vane clusters 30 can have either a clockwise twist or a counterclockwise twist. In this example, all of the vane clusters 30 have a counterclockwise twist relative to the direction of flow through the flow passage 28 (from left to right in the figure).

[0034] Figures 4-7 illustrate further example configurations with regard to the twist of the vane clusters 30. In these examples, the twist of the vane clusters is represented by illustrated clocking arrows. Each clocking arrow represents a direction of twist, either clockwise or counterclockwise, and a degree of twist that corresponds to the length of the arrow. In Figure 4, the hollow tube 24 includes two vane clusters that have a counterclockwise twist and another vane cluster that has a clockwise twist. In Figure 5, the hollow tube 324 has a progressively changing twist. From left to right in the figure, the first vane cluster has a relatively low degree of twist, the second vane cluster has a greater amount of twist than the first vane cluster, and the last vane cluster on the right-hand side has a third, greatest amount of twist. Thus, the fluid flowing through the hollow tube 24 is progressively swirled by a greater degree as it travels down the hollow tube 324.

[0035] The hollow tube 424 in Figure 6 has a twist that progressively changes between counterclockwise and clockwise. In this example, going from left to right in the figure, the first vane cluster has a counterclockwise twist, the second vane cluster has a lesser degree of counterclockwise twist, the third vane cluster has a clockwise twist, and the fourth vane cluster has a greater degree of clockwise twist. Thus, the swirl of the fluid traveling down the hollow tube 24 is gradually changed from counterclockwise to clockwise. As can be appreciated, the swirl could also go from clockwise to counterclockwise, and there could also be alternating segments of changing between clockwise, counterclockwise, and then back to clockwise.

[0036] The hollow tube 524 in Figure 7 has an alternating arrangement of vane clusters with regard to clockwise twist and counterclockwise twist. In this example, going from left to right in the figure, the first vane cluster has a counterclockwise twist, the second vane cluster a clockwise twist, the third vane cluster a counterclockwise twist, and the last vane cluster a clockwise twist. The segments shown in the above example are representative, and in further examples, these segments can be repeated or combined with one another to facilitate swirling of the fluid and uniform heat distribution.

[0037] Figure 8 illustrates another example hollow tube 624, which can be internally similar to any of the examples above. In this example though, the hollow tube 624 also includes a plurality of protrusions 660 extending outwardly from the exterior surface 26b. The protrusions 660 increase surface area and thus further promote heat transfer. The protrusions 660 can be fins, pins, or combinations thereof, but are not limited to such structures.

[0038] Although a combination of features is shown in the illustrated examples, not all of them need to be combined to realize the benefits of various embodiments of this disclosure. In other words, a system designed according to an embodiment of this disclosure will not necessarily include all of the features shown in any one of the Figures or all of the portions schematically shown in the Figures. Moreover, selected features of one example embodiment may be combined with selected features of other example embodiments.

[0039] The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

Claims

1. A heat exchanger article (22) comprising a hollow tube (24; 124; 224; 324; 424; 524; 624) including:

    a tube wall (26) with an interior surface (26a) and an exterior surface (26b), wherein the interior surface (26a) defines a flow passage (28) through the hollow tube (24; 124; 224; 324; 424; 524; 624); and
    a vane cluster (30) in the flow passage (28), wherein the vane cluster (30) includes a plurality of vanes (32; 132), and each of the vanes extends inwardly from the tube wall (26),
    characterized in that the hollow tube (24; 124; 224; 324; 424; 524; 624) is monolithic.

2. The heat exchanger article (22) as recited in claim 1, wherein the vanes (32; 132) of the vane cluster (30) extend inwardly toward a common central axis (A) of the hollow tube (24; 124; 224; 324; 424; 524; 624).

3. The heat exchanger article (22) as recited in claim 1 or 2, wherein the vanes (32; 132) of the vane cluster (30) meet at a central hub (42).

4. The heat exchanger article (22) as recited in claim 1, 2 or 3, wherein the hollow tube (624) includes a plurality of protrusions (660) extending outwardly from the exterior surface (26b).

5. The heat exchanger article (22) as recited in any preceding claim, wherein each of the vanes (32; 132) has a length from a vane leading edge (34) to a vane trailing edge (36) and a span from a vane outer side (38) to a vane inner side (40), and a ratio of the length

to the span is greater than 1:1.

6. The heat exchanger article (22) as recited in any preceding claim, comprising a series of said vane clusters (30) spaced apart in the flow passage (28).

7. The heat exchanger article (22) as recited in claim 6, wherein each of the vane clusters (30) has a twist, and the series of vane clusters has a progressively changing twist, wherein optionally the series of vane clusters has a progressively changing twist between clockwise twist and counter-clockwise twist.

8. The heat exchanger article (22) as recited in claim 6, wherein at least one of the vane clusters (30) has a clockwise twist and at least one other of the vane clusters (30) has a counter-clockwise twist.

9. The heat exchanger article (22) as recited in claim 6 or 8, wherein the series of vane clusters (30) has an alternating arrangement of vane clusters with regard to clockwise twist and counter-clockwise twist.

10. The heat exchanger article (22) as recited in any of claims 6 to 9, wherein the flow passage (28) is unobstructed between the vane clusters (30).

11. The heat exchanger article (22) as recited in any preceding claim, wherein the hollow monolithic tube (24; 124; 224; 324; 424; 524; 624) has first and second ends,
the tube wall (26) circumscribes the flow passage (28) that extends from the first end to the second end, and
the plurality of vanes (32; 132) are spaced from at least one of the first and second ends.

12. The heat exchanger article (22) as recited in any preceding claim, wherein each of the vanes (32; 132) has a twist from a vane leading edge (34) to a vane trailing edge (36).

13. The heat exchanger article (22) as recited in any preceding claim, wherein each of the vanes (32; 132) has an airfoil shape (150).

Patentansprüche

1. Wärmetauscherartikel (22) mit einem Hohlwellenrohr (24; 124; 224; 324; 424; 524; 624), das Folgendes beinhaltet:

   eine Rohrwand (26) mit einer Innenfläche (26a) und einer Außenfläche (26b), wobei die Innenfläche (26a) einen Strömungskanal (28) durch das Hohlwellenrohr (24; 124; 224; 324; 424; 524; 624) definiert; und
   ein Schaufelcluster (30) im Strömungskanal (28), wobei das Schaufelcluster (30) mehrere Schaufeln (32; 132) beinhaltet und sich jede der Schaufeln von der Rohrwand (26) nach innen erstreckt,
   dadurch gekennzeichnet, dass das Hohlwellenrohr (24; 124; 224; 324; 424; 524; 624) monolithisch ist.

2. Wärmetauscherartikel (22) nach Anspruch 1, wobei sich die Schaufeln (32; 132) des Schaufelclusters (30) nach innen zu einer gemeinsamen Mittelachse (A) des Hohlwellenrohres (24; 124; 224; 324; 424; 524; 624) erstrecken.

3. Wärmetauscherartikel (22) nach Anspruch 1 oder 2, wobei sich die Schaufeln (32; 132) des Schaufelclusters (30) an einer zentralen Nabe (42) treffen.

4. Wärmetauscherartikel (22) nach Anspruch 1, 2 oder 3, wobei das Hohlwellenrohr (624) mehrere Vorsprünge (660) beinhaltet, die sich von der Außenfläche (26b) nach außen erstrecken.

5. Wärmetauscherartikel (22) nach einem der vorhergehenden Ansprüche, wobei jede der Schaufeln (32; 132) eine Länge von einer Schaufelvorderkante (34) zu einer Schaufelhinterkante (36) und eine Spannweite von einer Schaufelaußenseite (38) zu einer Schaufelinnenseite (40) aufweist, und ein Verhältnis der Länge zu der Spannweite größer als 1:1 ist.

6. Wärmetauscherartikel (22) nach einem der vorhergehenden Ansprüche, umfassend eine Reihe der Schaufelcluster (30), die im Strömungskanal (28) voneinander beabstandet sind.

7. Wärmetauscherartikel (22) nach Anspruch 6, wobei jedes der Schaufelcluster (30) eine Verdrehung aufweist und die Reihe der Schaufelcluster eine sich progressiv ändernde Verdrehung aufweist, wobei die Reihe der Schaufelcluster optional eine sich progressiv ändernde Verdrehung zwischen Verdrehung im Uhrzeigersinn und Verdrehung gegen den Uhrzeigersinn aufweist.

8. Wärmetauscherartikel (22) nach Anspruch 6, wobei mindestens eines der Schaufelcluster (30) eine Verdrehung im Uhrzeigersinn und mindestens eines der anderen Schaufelcluster (30) eine Verdrehung gegen den Uhrzeigersinn aufweist.

9. Wärmetauscherartikel (22) nach Anspruch 6 oder 8, wobei die Reihe von Schaufelclustern (30) eine abwechselnde Anordnung von Schaufelclustern in Bezug auf Verdrehung im und gegen den Uhrzeigersinn aufweist.

10. Wärmetauscherartikel (22) nach einem der Ansprüche 6 bis 9, wobei der Strömungskanal (28) zwischen den Schaufelclustern (30) frei ist.

11. Wärmetauscherartikel (22) nach einem der vorhergehenden Ansprüche, wobei das hohle monolithische Wellenrohr (24; 124; 224; 324; 424; 524; 624) ein erstes und ein zweites Ende aufweist,
die Rohrwand (26) den Strömungskanal (28) umgibt, der sich vom ersten Ende bis zum zweiten Ende erstreckt, und
die mehreren Schaufeln (32; 132) von mindestens einem des ersten und zweiten Endes beabstandet sind.

12. Wärmetauscherartikel (22) nach einem der vorhergehenden Ansprüche, wobei jede der Schaufeln (32; 132) eine Verdrehung von einer Schaufelvorderkante (34) zu einer Schaufelhinterkante (36) aufweist.

13. Wärmetauscherartikel (22) nach einem der vorhergehenden Ansprüche, wobei jede der Schaufeln (32; 132) eine Flügelform (150) aufweist.

Revendications

1. Article d'échangeur de chaleur (22) comprenant un tube creux (24 ; 124 ; 224 ; 324 ; 424 ; 524 ; 624) incluant :

une paroi de tube (26) avec une surface intérieure (26a) et une surface extérieure (26b), dans lequel la surface intérieure (26a) définit une voie d'écoulement (28) à travers le tube creux (24 ; 124 ; 224 ; 324 ; 424 ; 524 ; 624) ; et un ensemble d'aubes (30) dans la voie d'écoulement (28), dans lequel l'ensemble d'aubes (30) inclut une pluralité d'aubes (32 ; 132), et chacune des aubes s'étend vers l'intérieur depuis la paroi de tube (26),
caractérisé en ce que le tube creux (24 ; 124 ; 224 ; 324 ; 424 ; 524 ; 624) est monolithique.

2. Article d'échangeur de chaleur (22) selon la revendication 1, dans lequel les aubes (32 ; 132) de l'ensemble d'aubes (30) s'étendent vers l'intérieur vers un axe central commun (A) du tube creux (24 ; 124 ; 224 ; 324 ; 424 ; 524 ; 624).

3. Article d'échangeur de chaleur (22) selon la revendication 1 ou 2, dans lequel les aubes (32 ; 132) de l'ensemble d'aubes (30) se rencontrent au niveau d'un moyeu central (42).

4. Article d'échangeur de chaleur (22) selon la revendication 1, 2 ou 3, dans lequel le tube creux (624) inclut une pluralité de protubérances (660) s'étendant vers l'extérieur depuis la surface extérieure (26b).

5. Article d'échangeur de chaleur (22) selon une quelconque revendication précédente, dans lequel chacune des aubes (32 ; 132) a une longueur depuis un bord d'attaque d'aube (34) jusqu'à un bord de fuite d'aube (36) et une envergure depuis un côté extérieur d'aube (38) jusqu'à un côté intérieur d'aube (40), et un rapport de la longueur à l'envergure est supérieur à 1:1.

6. Article d'échangeur de chaleur (22) selon une quelconque revendication précédente, comprenant une série desdits ensembles d'aubes (30) espacés les uns des autres dans la voie d'écoulement (28).

7. Article d'échangeur de chaleur (22) selon la revendication 6, dans lequel chacun des ensembles d'aubes (30) présente une torsion, et la série d'ensembles d'aubes présente une torsion changeant progressivement, dans lequel éventuellement la série d'ensembles d'aubes présente une torsion changeant progressivement entre une torsion dans le sens des aiguilles d'une montre et une torsion dans le sens contraire des aiguilles d'une montre.

8. Article d'échangeur de chaleur (22) selon la revendication 6, dans lequel au moins un des ensembles d'aubes (30) présente une torsion dans le sens des aiguilles d'une montre et au moins un autre des ensembles d'aubes (30) présente une torsion dans le sens contraire des aiguilles d'une montre.

9. Article d'échangeur de chaleur (22) selon la revendication 6 ou 8, dans lequel la série d'ensembles d'aubes (30) présente un agencement alterné d'ensembles d'aubes en ce qui a trait à la torsion dans le sens des aiguilles d'une montre et à la torsion dans le sens contraire des aiguilles d'une montre.

10. Article d'échangeur de chaleur (22) selon l'une quelconque des revendications 6 à 9, dans lequel la voie d'écoulement (28) n'est pas obstruée entre les ensembles d'aubes (30).

11. Article d'échangeur de chaleur (22) selon une quelconque revendication précédente, dans lequel le tube monolithique creux (24 ; 124 ; 224 ; 324 ; 424 ; 524 ; 624) présente des première et seconde extrémités,
la paroi de tube (26) circonscrit la voie d'écoulement (28) qui s'étend depuis la première extrémité jusqu'à la seconde extrémité, et
la pluralité d'aubes (32 ; 132) est espacée depuis au moins une des première et seconde extrémités.

12. Article d'échangeur de chaleur (22) selon une quelconque revendication précédente, dans lequel chacune des aubes (32 ; 132) présente une torsion depuis un bord d'attaque d'aube (34) vers un bord de fuite d'aube (36).

13. Article d'échangeur de chaleur (22) selon une quelconque revendication précédente, dans lequel chacune des aubes (32 ; 132) présente une forme de profil aérodynamique (150).

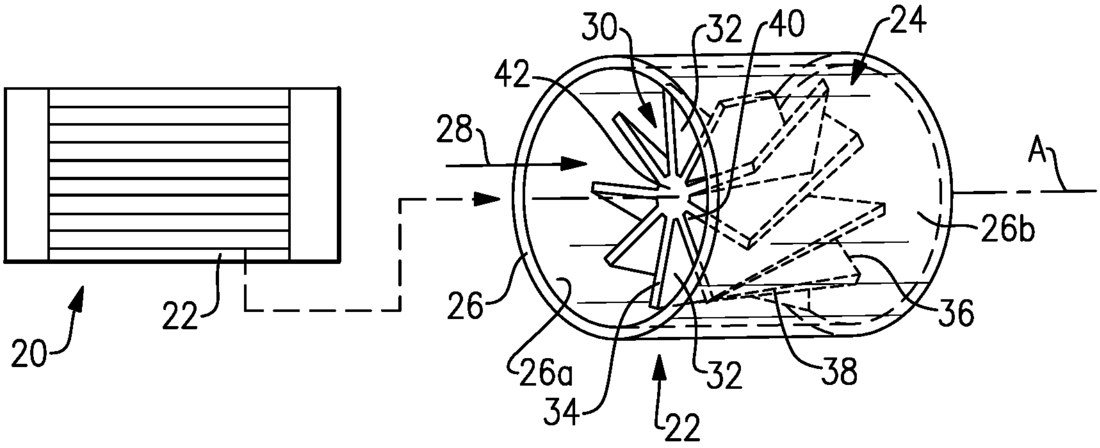

FIG.1

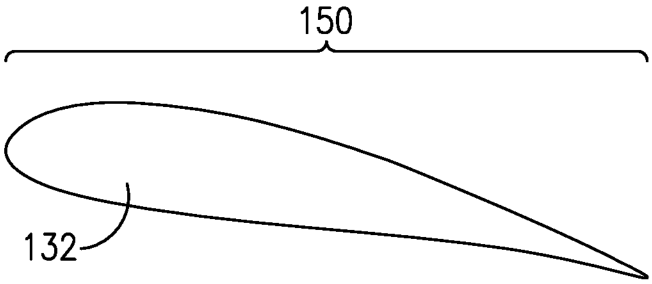

FIG.2

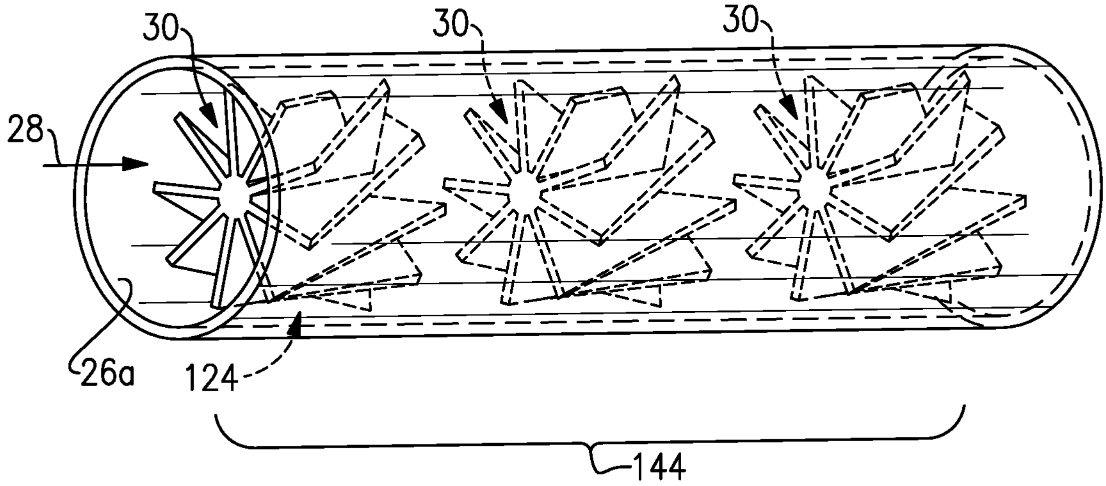

FIG.3

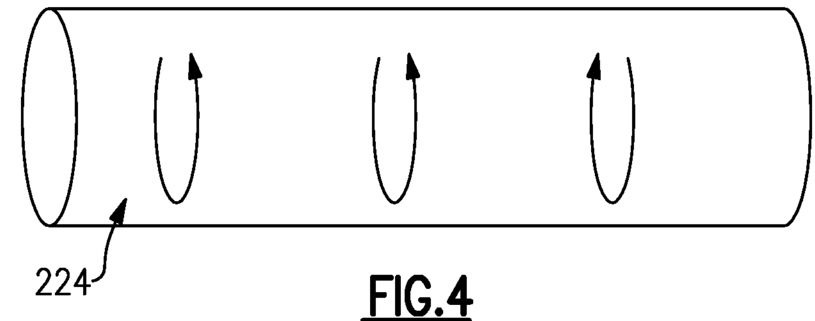

FIG.4

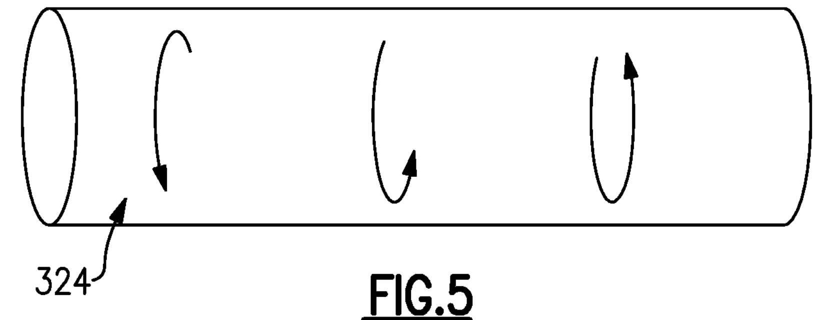

FIG.5

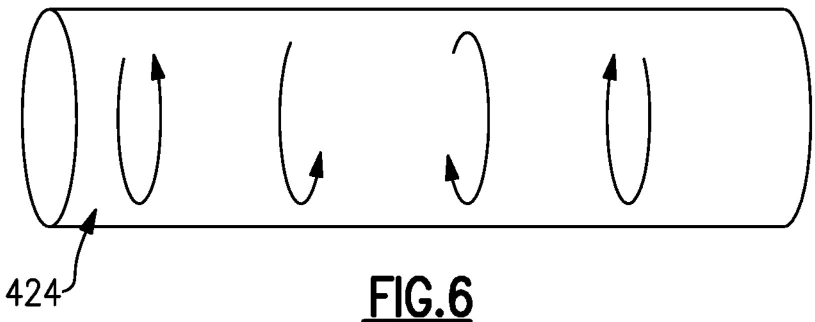

FIG.6

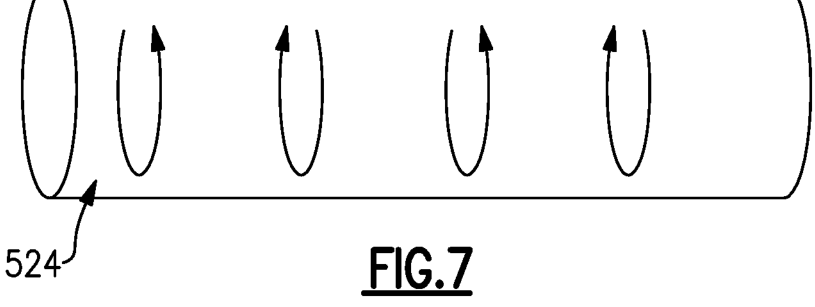

FIG.7

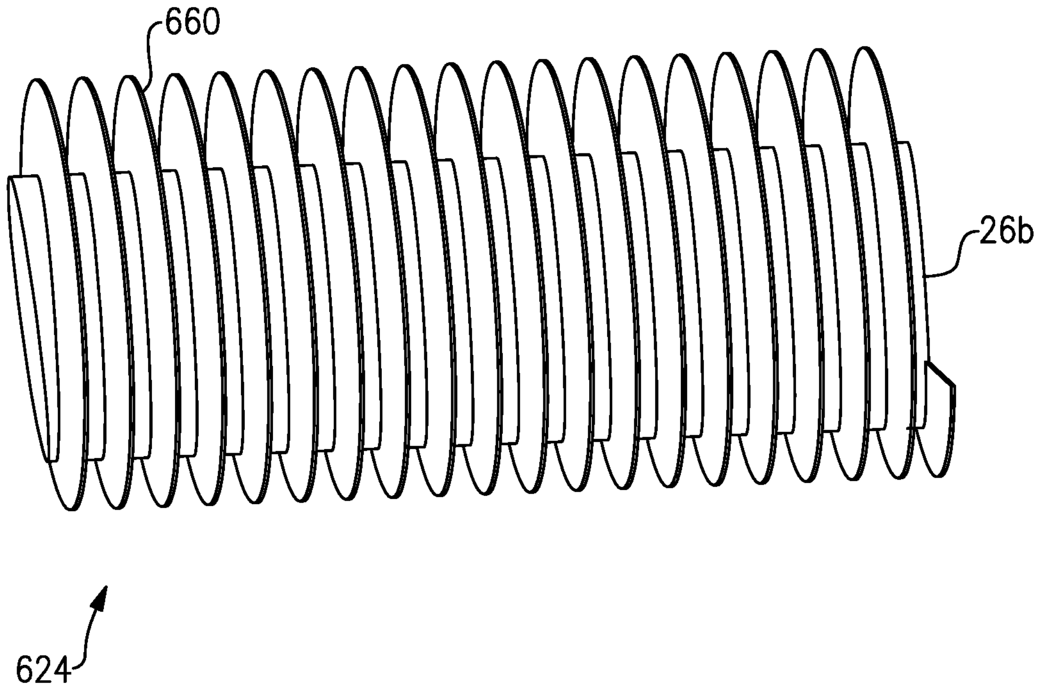

FIG.8

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 2011094721 A1 **[0003]**
- WO 2014125260 A1 **[0004]**
- GB 1359647 A **[0005]**