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

(57) A heat exchanger article (22) includes a hollow tube (24) that has a tube wall (26) with 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 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).

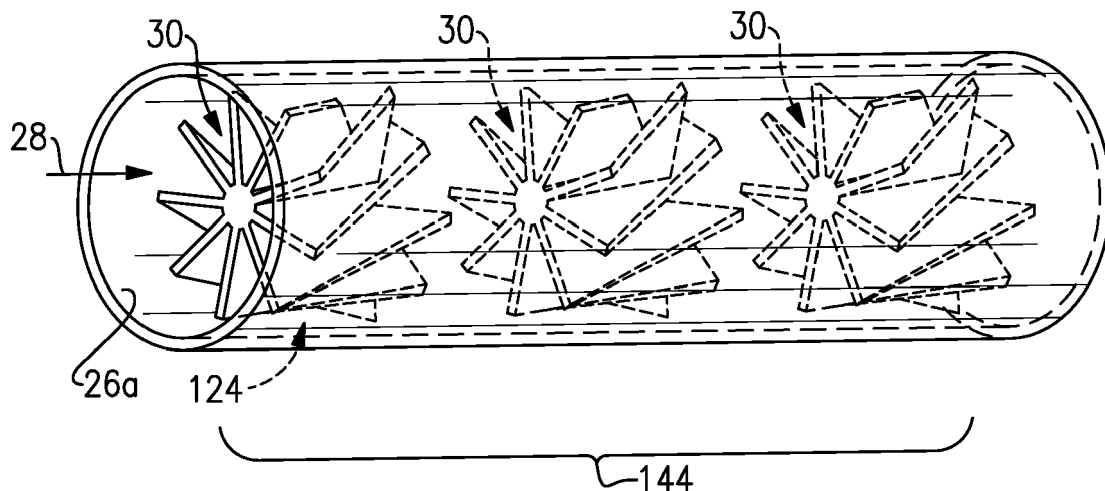


FIG.3

EP 3 054 253 A1

Description

BACKGROUND

[0001] This disclosure relates to heat exchangers and, more particularly, to heat exchanger tubes 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.

SUMMARY

[0003] A heat exchanger article according to an example of the present disclosure includes a 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.

[0004] 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.

[0005] 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.

[0006] In a further embodiment of any of the foregoing embodiments, each of the vanes has an airfoil shape.

[0007] In a further embodiment of any of the foregoing embodiments, the vanes of the vane cluster meet at a central hub.

[0008] In a further embodiment of any of the foregoing embodiments, the hollow tube includes a plurality of protrusions extending outwardly from the exterior surface.

[0009] 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.

[0010] In a further embodiment of any of the foregoing embodiments, the hollow tube is monolithic.

[0011] A heat exchanger article according to an example of the present disclosure includes a 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 series of vane clusters spaced apart in the flow passage. Each of the vane clusters includes a plurality of vanes, and each of the vanes extends inwardly from the tube wall.

[0012] 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.

[0013] 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.

[0014] 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.

[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 between clockwise twist and counter-clockwise twist.

[0016] In a further embodiment of any of the foregoing embodiments, the flow passage is unobstructed between the vane clusters.

[0017] In a further embodiment of any of the foregoing embodiments, the hollow tube is monolithic.

[0018] A heat exchanger article according to an example of the present disclosure includes a hollow monolithic tube that has first and second ends. The monolithic tube includes a tube wall that circumscribes a flow passage that extends from the first end to the second end, and a plurality of vanes that are spaced from at least one of the first and second ends and that extend inwardly from the tube wall.

[0019] 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.

[0020] 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.

[0021] In a further embodiment of any of the foregoing embodiments, each of the vanes has an airfoil shape.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] 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

[0023] 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.

[0024] 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.

[0025] 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.

[0026] 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.

[0027] 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.

[0028] 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 sides or the vanes 32 meet at a relatively smaller hub.

[0029] 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.

[0030] 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.

[0031] 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.

[0032] 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).

[0033] 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.

[0034] 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.

[0035] 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 has a clockwise twist, the third vane cluster has a counterclockwise twist, and the last vane cluster has 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.

[0036] 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.

[0037] 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.

[0038] 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 comprising a hollow tube including:
 - a tube wall with an interior surface and an exterior surface, wherein the interior surface defines a flow passage through the hollow tube; and
 - a vane cluster in the flow passage, wherein the vane cluster includes a plurality of vanes, and each of the vanes extends inwardly from the tube wall.
2. The heat exchanger article as recited in claim 1, wherein the vanes of the vane cluster extend inwardly toward a common central axis of the hollow tube.
3. The heat exchanger article as recited in claim 1 or 2, wherein the vanes of the vane cluster meet at a central hub.
4. The heat exchanger article as recited in claim 1, 2 or 3, wherein the hollow tube includes a plurality of protrusions extending outwardly from the exterior surface.
5. The heat exchanger article as recited in any preceding claim, wherein 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.
6. The heat exchanger article as recited in any preceding

ing claim, comprising a series of said vane clusters spaced apart in the flow passage.

7. The heat exchanger article as recited in claim 6, wherein each of the vane clusters 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. 5
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8. The heat exchanger article as recited in claim 6, wherein 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. 15
9. The heat exchanger article as recited in claim 6 or 8, wherein the series of vane clusters has an alternating arrangement of vane clusters with regard to clockwise twist and counter-clockwise twist. 20
10. The heat exchanger article as recited in any of claims 6 to 9, wherein the flow passage is unobstructed between the vane clusters.
11. The heat exchanger as recited in any preceding claim, wherein the hollow tube is monolithic. 25
12. A heat exchanger article comprising a hollow monolithic tube that has first and second ends, the monolithic tube including: 30
 - a tube wall that circumscribes a flow passage that extends from the first end to the second end; and
 - a plurality of vanes that are spaced from at least one of the first and second ends and that extend inwardly from the tube wall. 35
13. The heat exchanger article as recited in claim 12, wherein each of the vanes extends inwardly toward a common central axis of the monolithic tube. 40
14. The heat exchanger article as recited in any preceding claim, wherein each of the vanes has a twist from a vane leading edge to a vane trailing edge. 45
15. The heat exchanger article as recited in any preceding claim, wherein each of the vanes has an airfoil shape. 50

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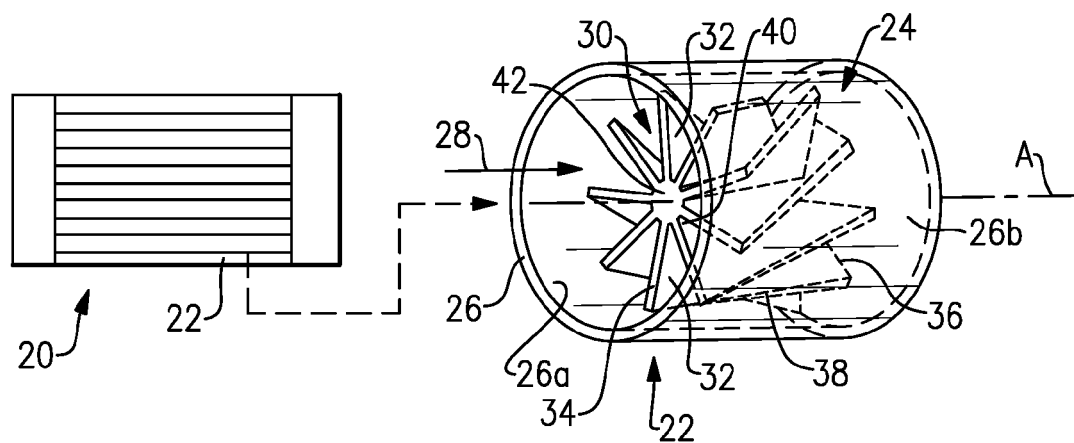


FIG. 1

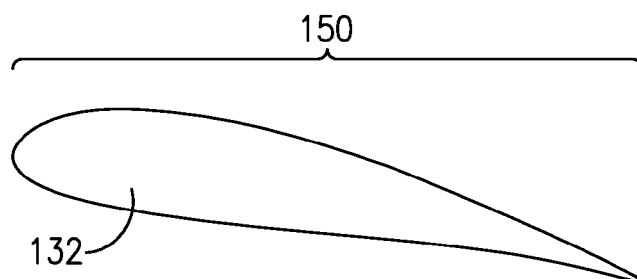


FIG. 2

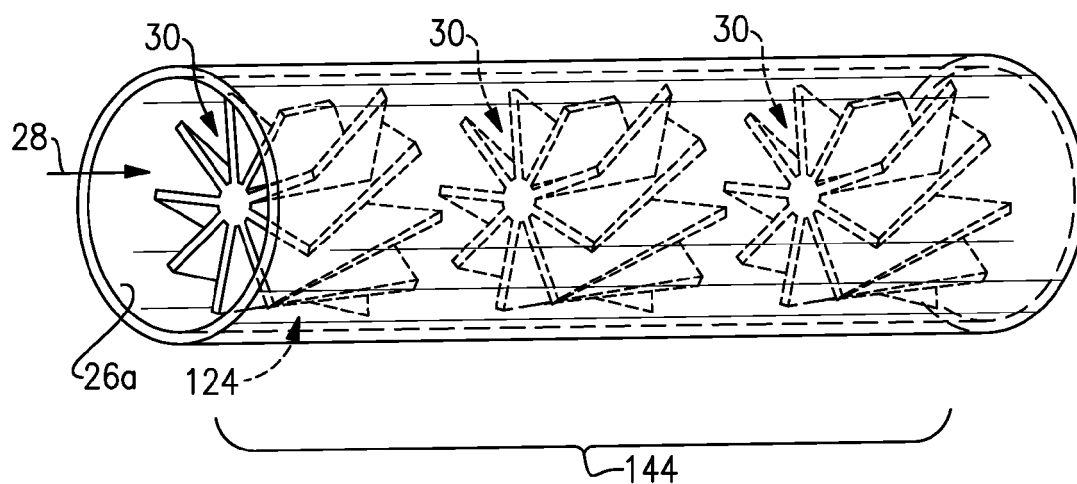
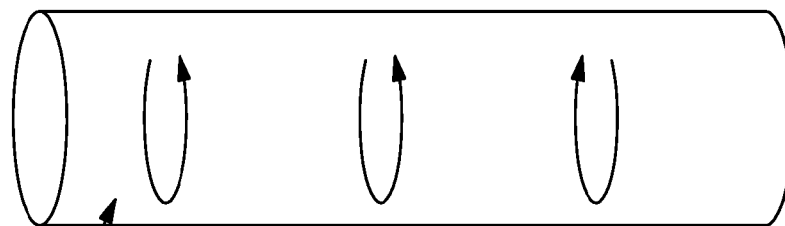
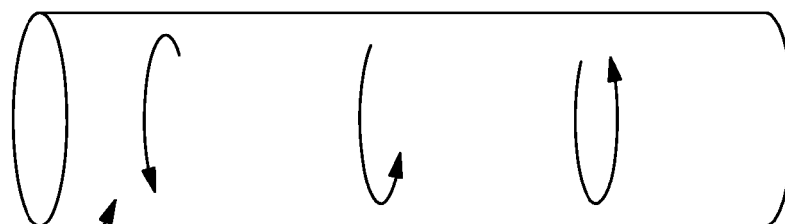


FIG. 3



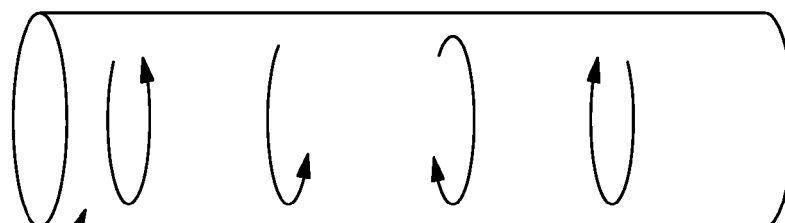
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FIG. 4



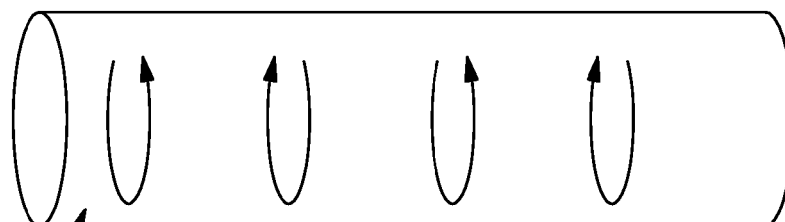
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FIG. 5



424

FIG. 6



524

FIG. 7

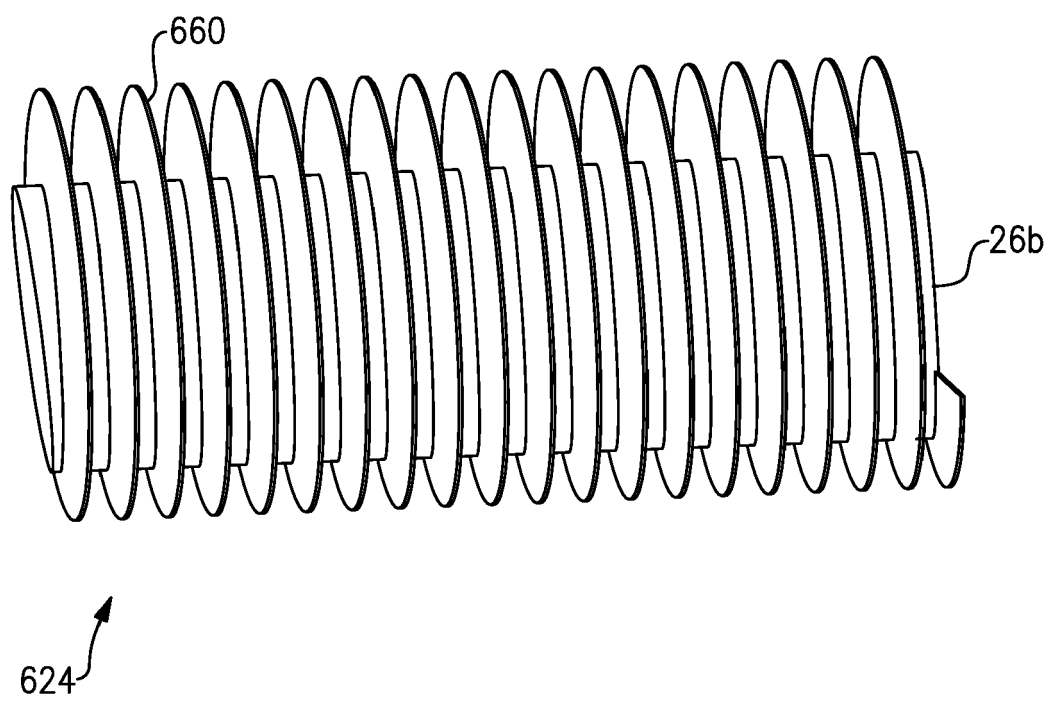


FIG.8



EUROPEAN SEARCH REPORT

Application Number
EP 16 15 4908

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 13 June 2016	Examiner Louchet, Nicolas
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