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(54) Corrugated tube with elliptical cross-section

(57) A corrugated tube (1; 21), with a corrugated inner surface (31) and a corrugated outer surface (32), is **characterized in that** the outer cross section (5a-5d; 43) of the corrugated tube (1; 21) is of elliptical or substantially elliptical shape. The invention provides a tube, in particular for use in a heat exchanging device, with an improved heat transfer efficiency.

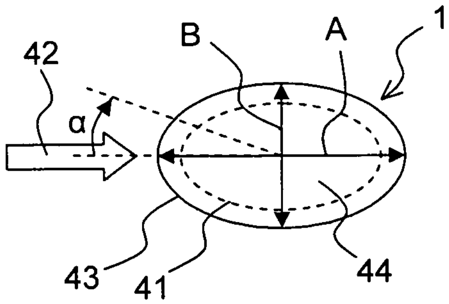

Fig. 4

EP 2 219 001 A1

Description

Background of the Invention

[0001] The invention relates to a corrugated tube, with a corrugated inner surface and a corrugated outer surface.

[0002] Such a corrugated tube, for use in a heat exchanging device, is known e.g. from commercial pipe systems of Brugg Rohrsysteme GmbH, Wunstorf, DE compare http://www.pipesystems.com/site/index.cfm?id_art=21588&actMenuItemID=122 29&vsprache/DE/Produkte_Industrie.cfm as available on 12.01.2009.

[0003] In heat exchanging devices, such as solar thermal systems, tubes are used as a separation for different fluids within a container. Through the walls of the tube, heat is transferred between the fluids. Generally, a high efficiency of the heat transfer is preferred in order to keep the heat exchanging devices small and thus cost efficient.

[0004] The most simple tubes for this purpose are plain tubes; however plain tubes have a relatively low heat transfer efficiency. It is known to improve the heat transfer by using finned tubes. The fins increase the surface of the tube on its outer side. However, the heat transfer is asymmetric, with a higher heat transfer on the outer surface than on the inner, plain surface. Further, finned tubes are difficult to produce and quickly get dirty and exhibit fouling. Upon handling and installation, the fins can easily get damaged, and the finned tubes are relatively stiff and therefore difficult to bend during installation.

[0005] It is also known to use corrugated tubes with a circular cross-section to increase the heat transfer. The corrugation increases the surface area as compared to plain tubes. Further, the corrugated inner and outer surface helps to make fluid flow turbulent, which also improves the heat transfer. Corrugated tubes can be furnished with good flexibility for simple handling and installation. However, it has been recognized by the inventors that such corrugated tubes exhibit local areas of low heat transfer in practice, what decreases the overall heat transfer efficiency.

Object of the Invention

[0006] It is the object of the invention to provide a tube, in particular for use in a heat exchanging device, with an improved heat transfer efficiency.

Summary of the Invention

[0007] This object is achieved, in accordance with the invention, by a corrugated tube as introduced in the beginning, **characterized in that** the outer cross section of the corrugated tube is of elliptical or substantially elliptical shape.

[0008] The inventive tube shape allows to direct an oncoming fluid flow onto the outer tube surface in a way such that the fluid flow is basically parallel to the longer dimension of the elliptical outer cross-section. Then, the tube offers a relatively narrow, edge-shaped profile to the oncoming fluid, what results in a smooth fluid flow in the vicinity of the outer tube surface. Strong turbulences and areas with a low bypassing flow on the outer surface are reduced or even avoided.

[0009] An inventive tube, with an oncoming flow in parallel to the longer side of the elliptical cross-section, results in a lower flow resistance as compared to a circular cross-section. With a turbulent flow (Reynold's number > 10^5), a circular cross-sectional shape results in a drag coefficient of between 0.4 and 1.2, whereas an inventive elliptical cross-sectional shape results in a drag coefficient of only 0.05 to 0.1, with a ratio of semi-minor to semi-major axis of 0.55.

[0010] As a result, areas of low heat transfer, which are common for conventional corrugated tubes with a circular cross-section due to the formation of pronounced stagnation points or break-off points, are reduced or even eliminated. Further, the inventive elliptical outer cross-section offers a larger outer surface area as compared to a circular cross-section with respect to the same cross-sectional area, what also improves the heat transfer between a fluid flowing within the tube and fluid flowing around the tube.

[0011] The corrugated shape also helps to increase the flexibility of the tube and thus facilitates handling and installation. Moreover, as compared to a plain tube, the surface area is also increased. Finally, the corrugated shape on the outer surface and on the inner surface helps to shift the flow in the vicinity of the tube from laminar to turbulent already at relatively low flow speeds; a turbulent flow is preferred due to its better heat transfer efficiency.

[0012] The cross-section of the inventive tube is taken in a plane perpendicular to the direction in which the tube extends. The outer cross-section of the tube is non-circular, and at least substantially elliptical. In other words, the cross-sectional shape is round and elongated, in accordance with the invention. Small deviations from an exactly elliptical cross-section do not affect the benefits of the invention. The aspect ratio, i.e. the ratio of the largest diameter (corresponding to the semi-major axis) and the diameter perpendicular to the largest diameter (corresponding to the semi-minor axis) of the outer cross-section is preferably 1.2 or more, particularly preferably 1.5 or more. The corrugations manifest in alternating bulges and depressions on the tube surface along the direction in which the tube extends. It is noted that the corrugations can be realized, in particular, by a spiral structure or a sequence of closed ring-shaped bulges.

Preferred embodiments of the invention

[0013] In a preferred embodiment of the inventive corrugated tube, also the inner cross section of the corrugated tube is of elliptical or substantially elliptical shape. In other words, the inner cross-section is non-circular, round and elongated in shape. The aspect ratio, i.e. the ratio of the largest diameter (corresponding to a semi-major axis) and the diameter perpendicular to the largest diameter (corresponding to a semi-minor axis) of the inner cross-section is preferably 1.2 or more, particularly preferably 1.5 or more. By means of this embodiment, the benefits of an elliptical shape, in particular the increased surface area, can also be used for the fluid flowing in the interior of the tube.

[0014] In a particularly preferred embodiment, the corrugated tube has a uniform wall thickness. Such a tube is simple to manufacture, and the heat transfer is basically symmetrical on the outer and inner surface of the tube.

[0015] Highly preferred is an embodiment wherein the corrugated tube is flexible. This simplifies handling and installation. The tube can be bent, according to the invention, manually without tools. The corrugated shape is particular suitable for a high flexibility. The flexibility can also be influenced by choosing the tube material properly.

[0016] In a preferred embodiment, the corrugated tube is made of a sheet metal or a plastic material. Sheet metal is a good heat conductor. Plastic material is particularly simple to process and inexpensive, and can provide a good flexibility.

[0017] In a particularly preferred embodiment, the ratio A/B of the semi-major axis A and the semi-minor axis B of the elliptical outer cross section is 1.2 or more, and preferably 1.5 or more. From these ratios on, the benefits as compared to a circular cross-section, become particularly significant. The above ratios are also preferred for an inner elliptical cross-section.

[0018] Also within the scope of the present invention is the use of an inventive corrugated tube for transferring heat between a first fluid flowing within the corrugated tube along the direction in which the corrugated tube extends, and a second fluid flowing around the corrugated tube. With the inventive corrugated tube, the efficiency of the heat transfer between the first and second fluid can be improved significantly as compared to conventional corrugated tubes with a circular cross-section.

[0019] In a highly preferred variant of the inventive use, the second fluid has an oncoming flow direction basically parallel to the semi-major axis of the elliptical outer cross section. In this orientation, the flow behaviour of the second fluid is particularly beneficial, and the heat transfer is particularly efficient.

[0020] Also preferred is a variant wherein the second fluid has an oncoming flow direction whose component perpendicular to the direction in which the tube extends is basically parallel to the semi-major axis of the elliptical outer cross section. This also results in a highly efficient heat transfer due to the large surface area presented in parallel to the flow direction.

[0021] Further preferred is a variant, wherein the second fluid has an oncoming flow direction basically perpendicular to the direction in which the corrugated tube extends. The second flow perpendicular to the direction in which the tube extends ("tube axis") quickly brings fresh second fluid to the tube wall.

[0022] In a particularly preferred variant, the first fluid and/or the second fluid are in turbulent flow. Under turbulent flow conditions, the heat transfer is particularly efficient.

[0023] Finally, a preferred variant of the inventive use is **characterized in that** the corrugated tube is part of a solar thermal system. For solar thermal systems, a high heat transfer efficiency is desired in order to be able to make use of even small sunlight quantities.

[0024] Further advantages can be extracted from the description and the enclosed drawing. The features mentioned above and below can be used in accordance with the invention either individually or collectively in any combination. The embodiments mentioned are not to be understood as exhaustive enumeration but rather have exemplary character for the description of the invention.

Drawing

[0025] The invention is shown in the drawing.

Fig. 1a shows schematically a first embodiment of an inventive corrugated tube, with subsequent closed ring-shaped bulges, in a cross-section parallel to the tube axis;

Fig. 1b shows the tube of Fig. 1a in cross-sectional views perpendicular to the tube axis, taken at planes AA, BB of Fig. 1a;

Fig. 2a shows a schematically a second embodiment of an inventive corrugated tube, with a spiral shape, in a cross-section parallel to the tube axis;

Fig. 2b shows the tube of Fig. 2a in cross-sectional views perpendicular to the tube axis, taken at planes CC, DD of Fig. 2a;

Fig. 3 shows a schematical, enlarged view of a tube wall of the inventive corrugated tube of Fig. 1a;

Fig. 4 shows a schematically an onflow of a fluid onto the outer surface of an inventive corrugated tube, in a cross-sectional view perpendicular to the tube axis.

[0026] **Fig. 1a** shows an inventive corrugated tube 1 in a cross-sectional view taken in parallel to a direction 2 in which the tube 1 extends. The tube 1 is straight in the example shown, therefore the direction 2 can also be called the tube axis. The tube 1 has a uniform wall thickness, wherein the wall thickness is neglected in Fig. 1. The corrugation of the tube 1 is along the direction 2.

[0027] The corrugated tube 1 comprises a sequence of bulges 3 and depressions 4. In the example shown, the bulges 3 and depressions 4 are closed ring-shaped, with the ring plane perpendicular to the direction 2. Therefore, the outer cross-section of the tube 1 varies in its dimensions along the direction 2.

[0028] **Fig. 1b** shows the outer cross-sections of the tube 1 of Fig. 1a in plane AA, see cross-section 5a, and in plane BB, see cross-section 5b. Planes AA, BB are perpendicular to the (local) direction 2 in which the tube 1 extends. The outer cross-sections 5a, 5b are elliptical and concentric, with the cross-section 5a, taken at a bulge 3, being larger than the cross-section 5b, taken at a depression 4.

[0029] **Fig. 2a** shows another inventive corrugated tube 21 in a cross-sectional view taken in parallel to the direction 2 in which the tube 21 extends. Again, the tube 21 is straight, so direction 2 can also be called the tube axis. The tube 21 has a uniform wall thickness, which is not detailed in the Fig. 2a. The corrugation is along the direction 2 again.

[0030] The corrugated tube 21 is of spiral type, with a single bulge 22 winding around the center (compare arrow of direction 2) of the tube 21, compare the trace 23 of the bulge 22 (only shown for a top tube part). Therefore, the outer cross-section of the tube 21 does not vary in its dimensions along the direction 2, but only in its position.

[0031] **Fig. 2b** shows the outer cross-section of the tube 21 of Fig. 2a in a plane CC, see cross-section 5c, and in a plane DD, see cross-section 5d. Planes CC, DD are perpendicular to the (local) direction 2 in which the tube 21 extends, and have a distance along direction 2 corresponding to half of a turn of the bulge 22 around the tube center. The outer cross-sections 5c, 5d are both elliptic and of equal size, but they are somewhat shifted against each other.

[0032] The shift of the cross-sections 5c, 5d may help to establish a turbulent flow in the interior of the tube 21 even at relatively low flow speeds.

[0033] Although tubes 1, 21 in Figs. 1 a and 2a are shown with a straight extension, inventive tubes may also have bent (curved) shapes. Preferably, the tubes 1, 21 are made of a flexible material.

[0034] **Fig. 3** shows an enlarged cross-sectional view of the tube 1 of Fig. 1a, namely the top left-side wall part. The tube 1 has a uniform wall thickness W along the direction 2, wherein the wall thickness W is measured in a plane perpendicular to the direction 2 in which the tube 1 extends, and from the inner surface 31 to the outer surface 32 of the tube 1. Both the inner surface 31 and the outer surface 32 are corrugated.

[0035] **Fig. 4** illustrates the orientation of an inventive tube 1 relative to the fluid flow. In Fig. 4, the tube 1 is shown in a cross-sectional view, taken in a plane perpendicular to the direction in which the tube 1 extends. In parallel to said direction, i.e. perpendicular to the plane of the drawing of Fig. 4, flows a first fluid in the interior 44 of the tube 1. The interior 44 of the tube 1 is limited by its inner surface; in Fig. 4, only the elliptical inner cross-section 41, shown with a dashed line, is visible.

[0036] Around the tube 1 flows a second fluid, compare oncoming flow 42. The tube 1 is limited to the outside by its outer surface; in Fig. 4, only the elliptical outer cross-section 43 is visible.

[0037] Fig. 4 shows the semi-major axis A and the semi-minor axis B of the outer cross-section 43. The ratio A/B is here about 1.7. The oncoming flow 42 is, with its component in the plane perpendicular to the (local) direction in which the tube 1 extends, in parallel to the semi-major axis A (note that a small angular deviation α, such as up to 10°, between said component of the oncoming flow 42 and the semi-major axis A would still be tolerable in accordance with the invention). Thus the tube 1 parts the oncoming flow 42 like a wedge, presenting only its narrower side to the oncoming flow 42, with the most protruding edge having the strongest curvature of the elliptic outer cross-section 43. As a result, the flow of the second fluid around the tube 1 is smooth, and the tube 1 represents only a low flow resistance. The heat exchange between the first fluid flowing in the interior 44 and the second fluid flowing around the tube 1 is very efficient then. In the example shown, the oncoming flow 42 is further perpendicular to the direction in which the tube extends (note that this is an option with respect to the invention).

[0038] Note that small deviations of the outer cross-section 43 or the inner cross-section 41 from an exactly elliptic shape would not affect the benefits of the invention.

[0039] The first fluid and/or the second fluid may be a liquid, in particular water or water mixed with an antifreeze agent, or a gas, in particular air, dried air or dried nitrogen.

Claims

1. Corrugated tube (1; 21), with a corrugated inner surface (31) and a corrugated outer surface (32), **characterized in that** the outer cross section (5a-5d; 43) of the corrugated tube (1; 21) is of elliptical or substantially elliptical shape.

2. Corrugated tube (1; 21) according to claim 1, **characterized in that** also the inner cross section (41) of the corrugated tube (1; 21) is of elliptical or substantially elliptical shape.

3. Corrugated tube (1; 21) according to claim 1, **characterized in that** the corrugated tube (1; 21) has a uniform wall thickness (W).

4. Corrugated tube (1; 21) according to claim 1, **characterized in that** the corrugated tube (1; 21) is flexible.

5. Corrugated tube (1; 21) according to claim 1, **characterized in that** the corrugated tube (1; 21) is made of a sheet metal or a plastic material.

6. Corrugated tube (1; 21) according to claim 1, **characterized in that** the ratio A/B of the semi-major axis A and the semi-minor axis B of the elliptical outer cross section (5a-5d; 43) is 1.2 or more, and preferably 1.5 or more.

7. Use of a corrugated tube (1; 21) according to claim 1 for transferring heat between a first fluid flowing within the corrugated tube (1; 21) along the direction (2) in which the corrugated tube (1; 21) extends, and a second fluid flowing around the corrugated tube (1; 21).

8. Use according to claim 7, **characterized in that** the second fluid has an oncoming flow direction (42) basically parallel to the semi-major axis (A) of the elliptical outer cross section (5a-5d; 43).

9. Use according to claim 7, **characterized in that** the second fluid has an oncoming flow direction (42) whose component perpendicular to the direction (2) in which the tube (1; 21) extends is basically parallel to the semi-major axis (A) of the elliptical outer cross section (5a-5d; 43).

10. Use according to claim 7, **characterized in that** the second fluid has an oncoming flow direction (42) basically perpendicular to the direction (2) in which the corrugated tube (1; 21) extends.

11. Use according to claim 7, **characterized in that** the first fluid and/or the second fluid are in turbulent flow.

12. Use according to claim 7, **characterized in that** the corrugated tube (1; 21) is part of a solar thermal system.

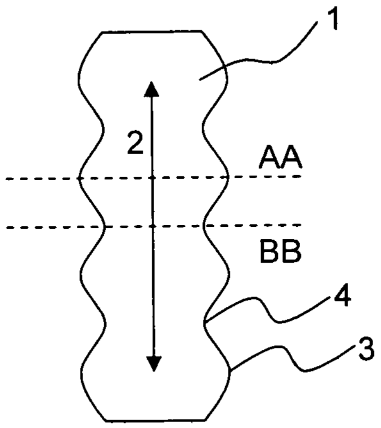

Fig. 1a

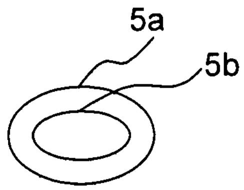

Fig. 1b

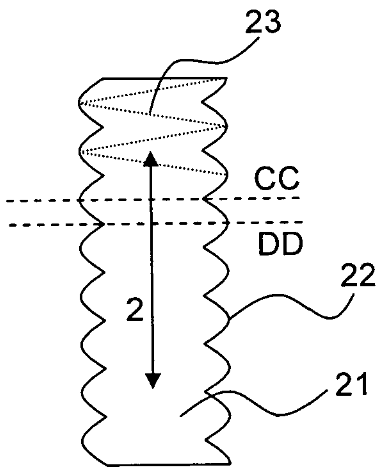

Fig. 2a

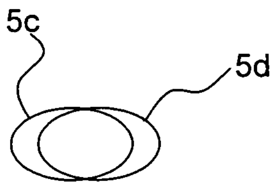

Fig. 2b

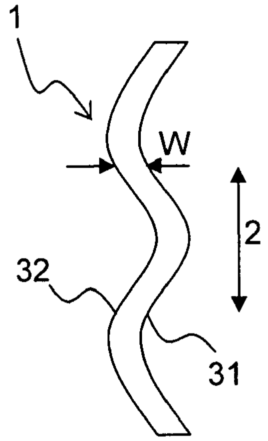

Fig. 3

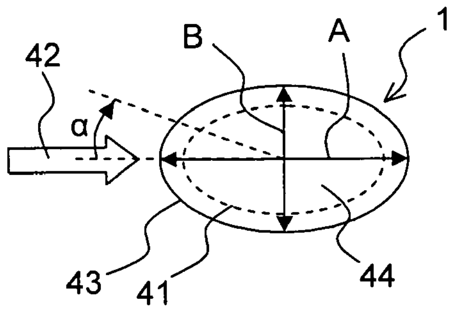

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 09 29 0111

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	14 July 2009	Vassoille, Bruno

CATEGORY OF CITED DOCUMENTS

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