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(54) **Title**: A GROOVED TUBE

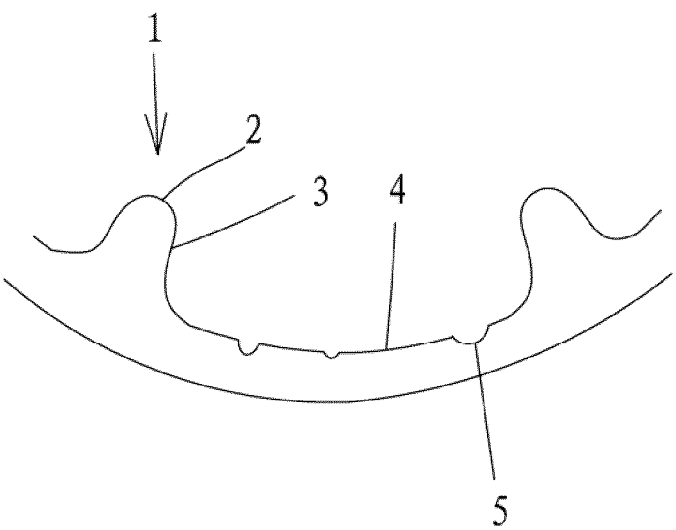

Fig. 2

(57) **Abstract**: The present disclosure presents a seamless grooved tube. The inner surface of the tube is grooved into a pattern, the pattern including at least one rib (1). At least a part of the at least one rib is roughened.

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A grooved tube

TECHNICAL FIELD

[001] The present invention relates to a grooved tube, in particular, to a seamless grooved tube for heat transfer.

BACKGROUND OF THE INVENTION

[002] A seamless tube, especially those made of materials of high heat-conductivity such as copper and aluminum, are used in a heat exchanger to circulate heat-carrying fluid to transfer heat. The tube is internally grooved to increase the inner surface for larger heat exchange area between the heat-carrying fluid and the surface of the tube and to generate turbulence, which improves heat exchange efficiency.

[003] Employing a grooved tube instead of one with a smooth inner surface in a heat exchanger significantly improves heat exchange efficiency and thus saves energy for environment protection. Notwithstanding the improved efficiency, people, more and more environmentally conscious and worried about the potential effect of ever wider use of heat exchangers, are still pushing for higher heat exchange efficiency.

SUMMARY OF THE INVENTION

[004] It is an object of the present disclosure to provide a grooved tube with improved heat exchange efficiency. This object is achieved by a grooved tube, wherein

the inner surface of the tube is grooved into a pattern, the pattern including at least one rib. At least a part of the at least one rib is roughened.

[005] The roughened surface of the rib increases the contact area between the heat-carrying fluid and the inner surface of the tube and thus improves the heat exchange efficiency. Moreover, the rough surface provides more spots for bubble formation -“nucleation sites”- in comparison with a smooth surface. Bubble formation speeds up heat exchange and thus also improves the heat exchange efficiency.

[006] According to one embodiment of the present invention, the grooved tube is seamless.

[007] According to one embodiment of the present invention, the roughened part of the at least one rib comprises a plurality of recesses, the plurality of recesses being dimensioned such that the depths of the recesses range from 0.0001 mm to 0.01 mm and the sizes of the openings of the recesses at the plane of the bottom of the rib range from 0.0001 mm to 0.01 mm.

[008] According to one embodiment of the invention, the depths of the recesses are in the range of 0.001 mm to 0.005 mm and the sizes of the openings of the recesses at the plane of the bottom of the rib are in the range of 0.001 mm to 0.005 mm.

[009] According to one embodiment of the invention, the roughened part of the at least one rib comprises a plurality of protrusions, the plurality of protrusions being dimensioned such that heights of the protrusions range from 0.0001 mm to 0.01 mm and the sizes of the cross-sections at the bases of the protrusions range from 0.0001 mm to 0.01 mm.

[010] According to one embodiment of the invention, the heights of the protrusions are in the range of 0.001 mm to 0.005 mm and the sizes of the cross-sections at the bases of the protrusions are in the range of 0.001 mm to 0.005 mm.

[011] According to one embodiment of the invention, the at least one rib has a top, side surfaces, and a bottom, wherein the top and the side surfaces of the at least one rib are smooth, and at least a portion of the bottom of the at least one rib is roughened. By roughening the inner surface only at the bottom of the rib, more heat exchange surface and more spots for bubble formation are provided at the bottom, which significantly improves the heat exchange efficiency, while minimizing the impact on the flow of the heat-carrying fluid as the top and the side surfaces of the rib are left smooth.

[012] According to one embodiment of the invention, the tube is made of copper or copper alloy. The high thermal conductivity of copper and copper alloys results in high heat exchange efficiency of the tube according to this embodiment. Preferably, the tube is made of copper.

[013] According to one embodiment of the invention, the at least one rib is configured as a helix on the inner surface of the tube. The helical rib causes turbulence in the fluid and thus also improves heat exchange efficiency.

[014] According to one embodiment of the invention, the roughened part of the at least one rib is made by drawing the tube through a die, at least a part of the surface of the die being roughened so as to roughen the at least a part of the at least one rib during drawing.

[015] According to one embodiment of the invention, the roughened part of the at least one rib is made by sintering metal particles onto the part of the at least one rib to be roughened.

[016] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[017] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments of the invention and together with the description, serve to explain the principles of the invention.

[018] Fig. 1a shows the longitudinal cross-sectional view of a seamless grooved tube according to one embodiment of the present disclosure;

[019] Fig. 1b shows the transverse cross-sectional view of the seamless grooved tube shown in Fig. 1a;

[020] Fig. 2 is a cross-sectional view of a seamless grooved tube according to one embodiment of the present disclosure, illustrating the roughened inner surface of the tube;

[021] Fig. 3 is a cross-sectional view of a seamless grooved tube according to another embodiment of the present disclosure, illustrating the roughened inner surface of the tube.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[022] Fig. 1a shows the longitudinal cross-sectional view and Fig 1b shows the transverse cross-sectional view of a seamless grooved tube according to one embodiment of the present disclosure. The tube is seamless as it is made through drawing a solid billet over a piercing rod to create a hollow shell (in contrast, a welded tube is made by rolling a plate and welding two edges of the plate); the tube, however, may also be a welded one. The inner surface of the tube is grooved into a pattern. Although the tube shown in Fig. 1a and 1b is internally threaded, i.e., its inner surface is grooved into a helical thread, one skilled in the art knows that the inner surface can be grooved into any suitable pattern, e.g., a plurality of ribs extending along the longitudinal axis of the tube, or a helix on the inner surface of the tube. The grooved pattern shown in Fig. 1a and 1b includes at least one rib 1, which comprises a top 2, side surfaces 3, and a bottom 4. The presence of the rib 1 increases the area of the inner surface of the tube, and thus increases the heat exchange area between the heat-carrying fluid and the inner surface of the tube, and consequently gives higher heat exchange efficiency. The flow of the heat-carrying fluid is impacted by the rib 1; a portion of the fluid has to flow in conformity with the helical path along which the rib 1 extends, i.e., being guided by the rib 1 to flow in a helical manner, which causes turbulence in the fluid and thus also improves heat exchange efficiency.

[023] The heat exchange efficiency of the seamless grooved tube can be further improved by having at least a part of the surface of the rib 1 roughened. The roughened surface of the rib 1 can further increase the contact area between the heat-carrying fluid and the inner surface of the tube and thus further improves the heat

exchange efficiency. Moreover, the rough surface provides more spots for bubble formation (bubble formation is a phase transition, which results from a process named "nucleation", which usually happens on an interface such as a rough wall), whereby small bubbles will detach from the surface.

[024] The roughness can be distributed on the surface of the rib 1 in any suitable pattern. For example, the whole surface of the rib 1, including the top 2, the side surfaces 3, and the bottom 4, may be roughened; only the side surfaces 2 of the rib 1 is roughened; or the top 2 and the side surfaces 3 are roughened. Figs. 2 and 3 show two embodiments of the present disclosure where at least a portion of the bottom 4 of the rib 1 is roughened, yet the top 2 and the side surfaces 3 of the rib 1 are smooth. By roughening the inner surface only at the bottom 4 of the rib 1, more heat exchange surface and more spots for bubble formation are provided at the bottom 4, which significantly improves the heat exchange efficiency, while minimizing the impact on the flow of the heat-carrying fluid as the top 2 and the side surfaces 3 of the rib1 are left smooth.

[025] The roughened surface can take any suitable form. Fig. 2 demonstrates one form, where the bottom 4 of the rib 1 comprises a plurality of recesses 5. The recesses 5 are irregularly distributed on the bottom 4. The recesses 5 can be of any shape; e.g., a recess's opening at the plane of the bottom may be a substantial circle, a square or any other regular or irregular shape, and the opening tapers while extending downward so that the recess is formed into a substantial spherical cap/cone, an inverted pyramid or any other regular or irregular shape. The recesses 5 may be dimensioned such that the sizes of the openings (measured as the largest distance between two points of the circumference of the opening that are farthest from each

other) of the recesses 5 at the bottom 4 range from 0.0001 mm to 0.01 mm, and the depths of the recesses (measured from the plane of the bottom 4, i.e., the top of a recess 5, to the bottom of a recess 5) range from 0.0001 mm to 0.01 mm. For example, the size of the openings of the recesses 5 may be 0.0001 mm, 0.001 mm, 0.005 mm, or any size falling between 0.0001 mm and 0.005 mm. The depths of the recesses 5 may be 0.0001 mm, 0.001 mm, 0.005 mm, or any depth falling between 0.0001 mm and 0.005 mm.

[026] The roughened surface of the seamless grooved tube described above can be made via any suitable process. For example, the roughened surface may be made by drawing the tube through a die with at least a part of the surface of the die roughened so as to roughen the at least a part of the at least one rib during drawing.

[027] Fig. 3 demonstrates another embodiment of a roughened surface. The bottom 4 of the rib 1 comprises a plurality of protrusions. The protrusions 6 are irregularly distributed on the bottom 4. The protrusions 6 can be of any shape; e.g., the cross section of a protrusion 6 taken along a plane parallel to the bottom 4 may be a substantial circle, square, or any other regular or irregular shape, and the cross-section tapers towards the tip of the protrusion so that the recess is formed into a substantial cone, pyramid or any other regular or irregular shape. The protrusions 6 may be dimensioned such that the sizes of the cross-section (measured as the largest distance between two points of the circumference of the cross-section that are farthest from each other) of at the respective bases of protrusions range from 0.0001 mm to 0.01 mm, and the heights of the protrusions 6 range from 0.0001 mm to 0.01 mm. For example, the sizes of the cross-sections of the bases of the protrusions may be 0.0001 mm, 0.001

mm, 0.005 mm or values between theses sizes. The heights of the protrusions may be 0.0001 mm, 0.001 mm, 0.005 mm or values between theses sizes.

[028] The roughened surface of the seamless grooved tube described above can be made via any suitable process. For example, it can be made by sintering metal particles onto the corresponding inner surface. Specifically, a core rod is inserted into the tube, with a gap reserved between the inner wall of the tube and the core rod; metal particles are filled into the part of the gap that corresponds to the roughened surface, and then the tube with the core rod and the metal particles are heated so that the metal particles are sintered on the part of the inner surface to be roughened.

[029] Experiments have been done on 7 mm inner-grooved tubes to compare the heat exchange efficiency between inner grooved tubes with roughened inner surface and those with smooth inner surfaces. As experiments show, the heat exchange efficiency of a heat exchanger with the above-described grooved tubes with roughened inner surface can be improved by approximately 20% relative to a heat exchanger with grooved tubes with smooth inner surface, which significantly saves energy.

[030] In the preceding specification, various preferred embodiments have been described with reference to the accompanying drawings. It will, however, be evident that various other modifications and changes may be made thereto, and additional embodiments may be implemented, without departing from the broader scope of the invention as set forth in the claims that follow. The specification and drawings are accordingly to be regarded in an illustrative rather than restrictive sense.

[031] Other embodiments of the disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the disclosure disclosed herein. It is intended that the specification and examples be considered as exemplary

only, with the true scope and spirit of the invention being indicated by the following claims.

CLAIMS

1. A grooved tube, wherein the inner surface of the tube is grooved into a pattern, the pattern including at least one rib (1), wherein at least a part of the at least one rib (1) is roughened.

2. The grooved tube according to claim 1, wherein the grooved tube is seamless.

3. The grooved tube according to claim 1 or 2, wherein the roughened part of the at least one rib (1) comprises a plurality of recesses (5), the plurality of recesses (5) are dimensioned such that the depths of the recesses (5) range from 0.0001 mm to 0.01 mm and the sizes of the openings of the recesses (5) at the plane of the bottom (4) of the rib (1) range from 0.0001 mm to 0.01 mm.

4. The grooved tube according to claim 3, wherein the depths of the recesses (5) are in the range of 0.001 mm to 0.005 mm and the sizes of the openings of the recesses (5) at the plane of the bottom (4) of the rib (1) are in the range of 0.001 mm to 0.005 mm.

5. The grooved tube according to claim 1 or 2, wherein the roughened part of the at least one rib (1) comprises a plurality of protrusions (6), the plurality of protrusions (6) are dimensioned such that heights of the protrusions range from 0.0001

mm to 0.01 mm and the sizes of the cross-sections at the bases of the protrusions (6) range from 0.0001 to 0.01 mm.

6. The grooved tube according to claim 5, wherein the heights of the protrusions (6) are in the range of 0.001 mm to 0.005 mm and the sizes of the cross-sections at the bases of the protrusions (6) are in the range of 0.001 mm to 0.005 mm.

7. The grooved tube according to any one of claims 1–6, wherein the at least one rib (1) has a top (2), side surfaces (3), and a bottom (4), the top (2) and the side surfaces (3) of the at least one rib (1) are smooth, and at least a portion of the bottom (4) of the at least one rib (1) is roughened.

8. The grooved tube according to any one of claims 1–7, wherein the tube is made of copper or copper alloy.

9. The grooved tube according to any one of claims 1–8, wherein the at least one rib (1) is configured as a helix on the inner surface of the tube.

10. The grooved tube according to any one of claims 3–4, wherein the roughened part of the at least one rib (1) is made by drawing the tube through a die, at least a part of the surface of the die being roughened so as to roughen the at least a part of the at least one rib (1) during drawing.

11. The grooved tube according to any one of claims 7-10, wherein the roughened part of the at least one rib (1) is made by sintering metal particles onto the part of the at least one rib (1) to be roughened.

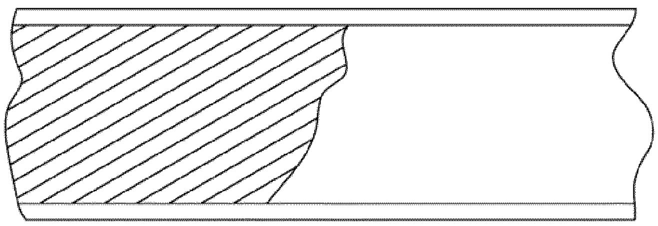

Fig. 1a

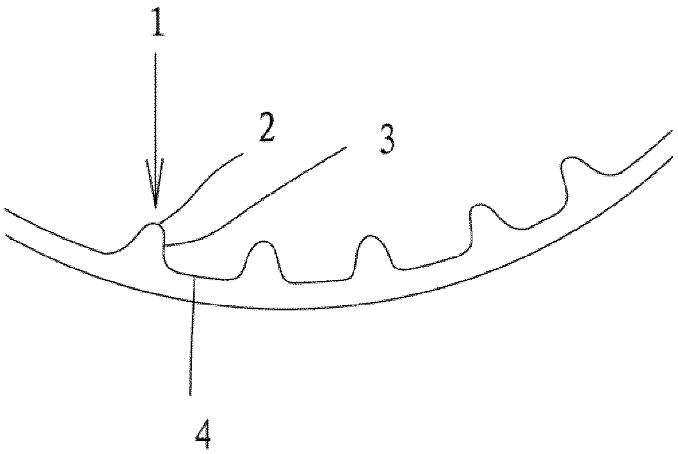

Fig 1b

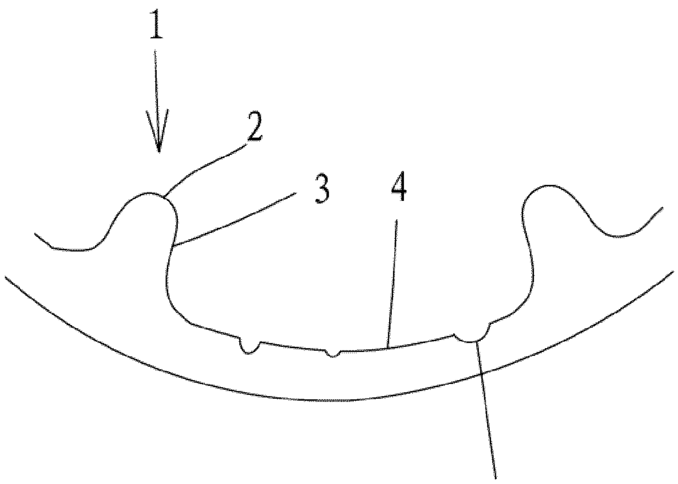

Fig. 2

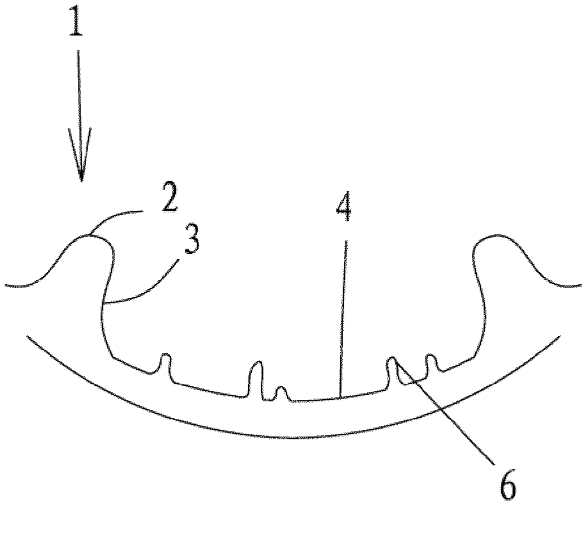

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/073110

A. CLASSIFICATION OF SUBJECT MATTER
INV. F28F1/40
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 January 2014	07/02/2014

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International application No
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