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(54) **COMPOUND HEAT PIPE, METHOD OF
MANUFACTURING THE SAME, HEAT
EXCHANGER AND HEAT EXCHANGER
SYSTEM USING THE SAME**

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(57) **ABSTRACT**

The compound heat pipe according to the present invention may overcome physical limits, which a single metal pipe might have, by integrally joining different metal pipes having different physical properties, forming ridges on an inner surface thereof the pipe and protrusions on an outer surface thereof and may first increase heat transfer capability by increasing the heat transfer area between the pipe and fluid. Further, the compound heat pipe according to the present invention may secondly increase the heat transfer capability by setting the noncontact rate to be 30% or less so that the heat transfer rate of the compound heat pipe in the radial direction may be optimized.

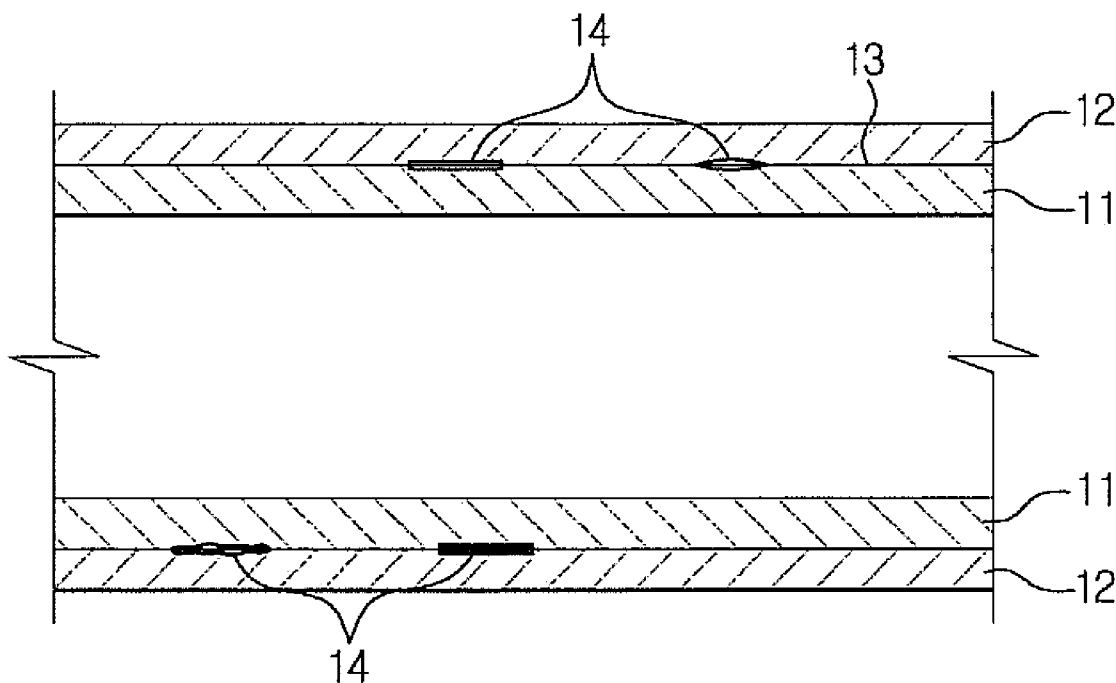


Fig. 1

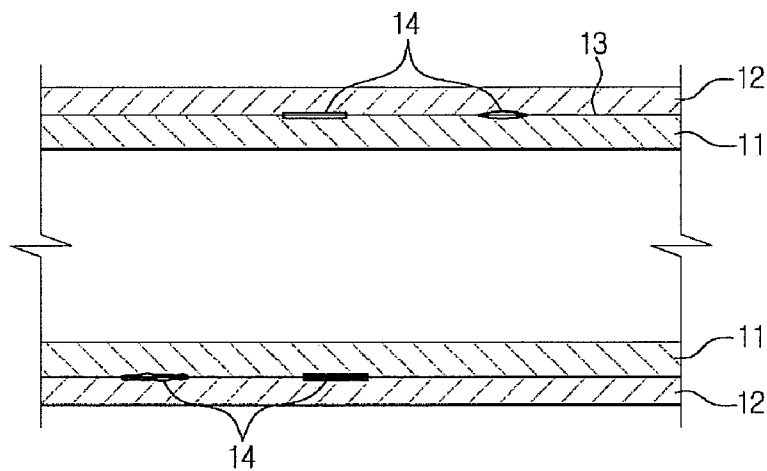


Fig. 2

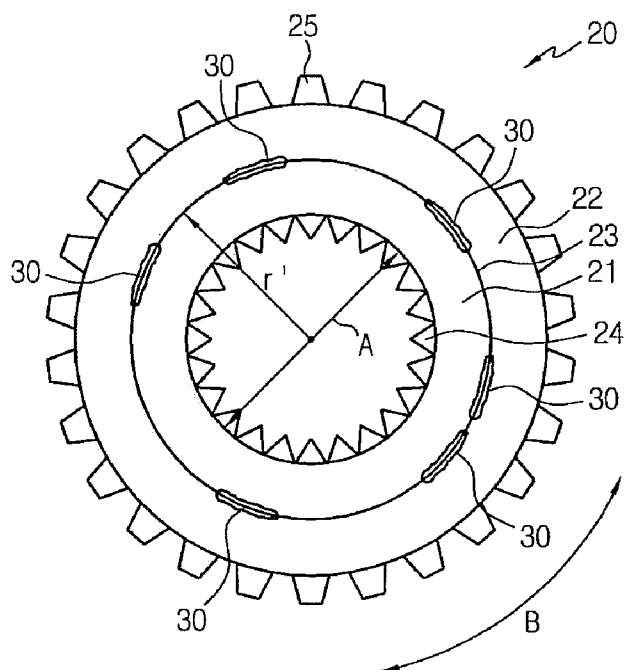


Fig. 3

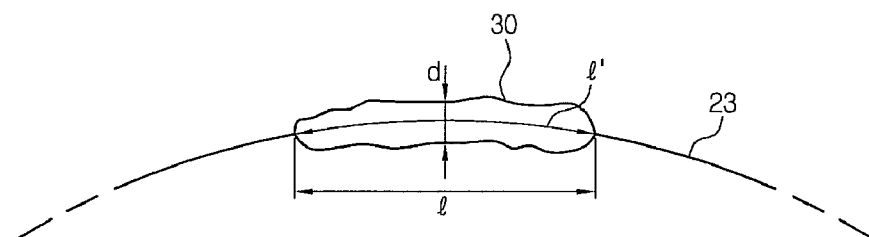


Fig. 4

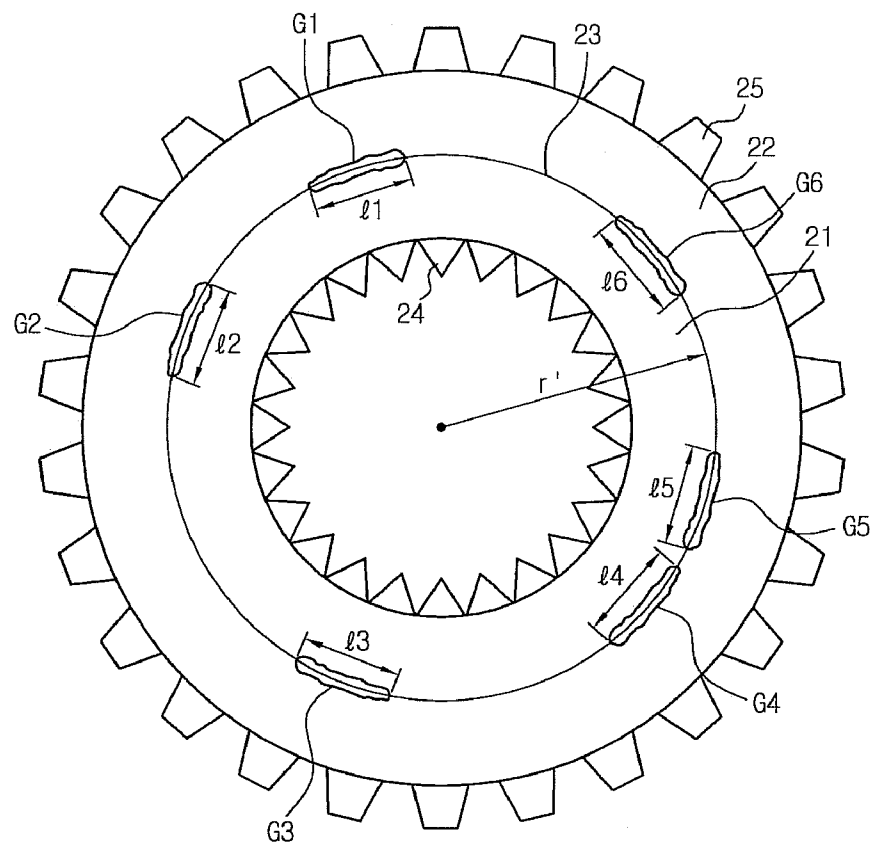


Fig. 5

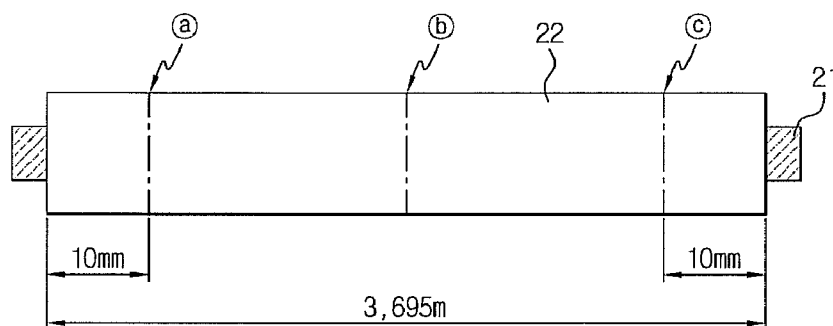
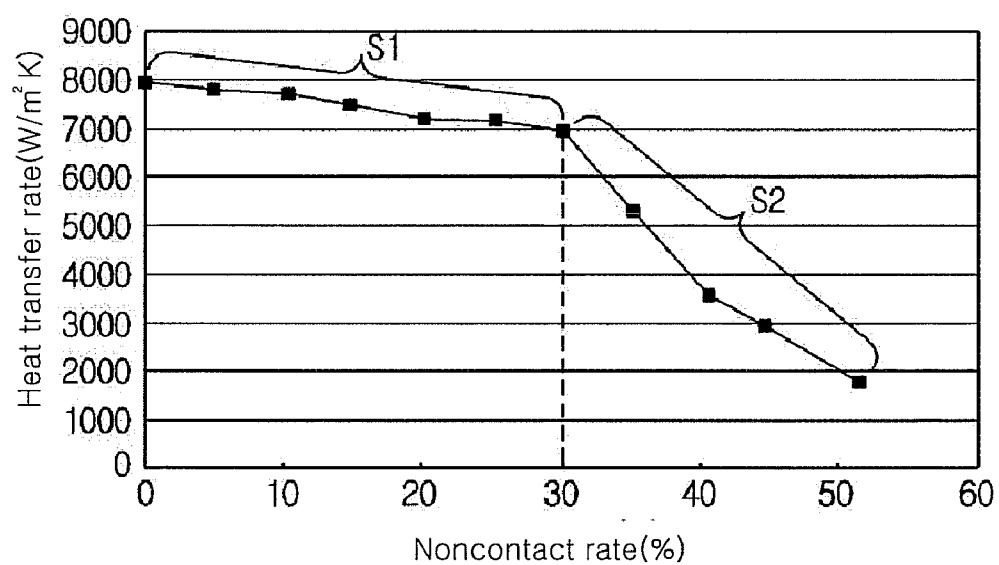


Fig. 6



COMPOUND HEAT PIPE, METHOD OF MANUFACTURING THE SAME, HEAT EXCHANGER AND HEAT EXCHANGER SYSTEM USING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Korean Patent Application No. 10-2010-0134810 filed on Dec. 24, 2010, the contents of which are herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Technical Field

[0003] The present invention relates to a heat pipe for a heat exchanger, and particularly to a compound heat pipe including metal materials having different physical properties.

[0004] 2. Discussion of the Related Art

[0005] In general, a heat exchanger system is provided in an industry facility, a room cooling/heating facility, or various mechanical apparatuses for performing heat exchanging operation. Such a heat exchanger system generally uses a heat pipe as a metal pipe for heat exchange. For instance, a heat pipe is used for heat exchange between cooling water and absorbing liquid and between cold water and coolant in an evaporator and an absorber of an absorbing chiller that uses a principle that liquid solubility of coolant steam varies with temperature and pressure. A heat pipe is also used for heat exchange between cooling water and coolant (R134a) in an evaporator of a turbo chiller.

[0006] Early heat pipes were made only of a single metal, such as copper or an alloy of copper, and included protrusions or metal fins at an outer surface thereof to raise heat exchange capability. For example, Korean Patent Nos. 0518695 and 0707682 and Korean Patent Application Publication Nos. 2007-63073, 2009-98526, and 2010-21215 disclose various methods for increasing heat exchange capability of heat pipes made of a single metal.

[0007] A typical method is to form a heat transfer fin or protrusion on an outer surface of the heat pipe and a twisted ridge or screwed protrusion on an inner surface of the heat pipe.

[0008] However, in the case that the heat pipe is made only of copper or an alloy of copper, various problems occurs due to unique characteristics of copper or the copper alloy. Copper or the copper alloy has excellent corrosion resistance, thermal conductivity, and mechanical properties, but has disadvantages, such as high price due to being poor in nature and heavy weight attributable to a high specific gravity. Because of being rich and low in cost, aluminum or alloys thereof attracts interest as a number-one alternative to copper. However, aluminum or aluminum alloys are poorer than copper in all of intensity, corrosion resistance, thermal conductivity, and other mechanical properties.

[0009] Recently, compound metal pipes made of both copper and aluminum are being developed. For example, Korean Patent Application Publication No. 2009-23349 (hereinafter, simply referred to as 'Patent Document 1') discloses a copper/aluminum compound pipe that includes an inner metal layer made of copper and an outer metal layer made of aluminum.

[0010] Also, Patent Document 2 (Japanese Patent Application Publication No. 2000-146304) discloses a fin tube type heat pipe having a plurality of fin mountains on the surface of

an outer metal layer, and Patent Document 3 (Japanese Patent Application Publication H6-198376) discloses a heat pipe that includes a spiral fin integrally formed on an outer circumferential surface of an outer metal layer, wherein the spiral fin includes a plurality of spiral slits to increase heat transfer capability of a compound pipe as disclosed in Patent Document 1.

SUMMARY

[0011] However, the compound heat pipes disclosed in Patent Documents 2 and 3 have limits to increasing heat transfer capability since heat transfer fins for prompting heat transfer capability are formed only on the surface of the outer metal layer.

[0012] Thus, there is a need for changing the structure, such as, for example, forming a ridge that may provide effects, such as expansion of heat transfer area and an increase in flow resistance, and turbulence effect on a fluid, to an inner surface of the heat pipe.

[0013] As such, if the ridge is formed on the inner surface as well as the outer surface of the compound heat pipe, a plurality of gaps **14** are created at an interface **13** between the inner metal layer **11** and the outer metal layer **12** as shown in FIG. 1. The existence of the gaps deteriorates heat transfer capability between a fluid flowing inside the heat pipe and a fluid flowing outside the heat pipe. Accordingly, it is crucial to control the size of the gaps at the interface between the inner and outer metal layers of the heat pipe in order to raise the heat transfer capability of the compound heat pipe. Under the above technical background, the inventors researched a mutual relationship between the size (noncontact rate) of the gaps existent at the interface of the compound heat pipe and the heat transfer rate.

[0014] A research result showed the heat transfer rate of the compound heat pipe is in inverse proportion to the noncontact rate of the interface of the compound heat pipe and the heat transfer rate sharply decreases near a certain noncontact rate.

[0015] The present invention has been made in the above technical motives and background, and a first technical object of the present invention is to provide a compound heat pipe having at least two or more different metal layers overlapping each other, wherein the outer surface and inner surface of the pipe are varied in structure to be able to maximize heat transfer capability.

[0016] A second object of the present invention is to optimize the heat transfer rate in the direction of the radius of the compound heat pipe by adjusting the noncontact rate of the interface between the inner and outer metal layers of the compound heat pipe.

[0017] Other objects and advantages of the present invention will be described below and apparent from the embodiments. And, the objects and advantages of the present invention may be implemented by configurations recited in claims and combinations of the configurations.

[0018] To achieve the above objects, a compound heat pipe according to the present invention includes a first pipe body having at least one or more protrusions on an outer surface of the first pipe body, wherein the first pipe body is formed of a first metal material; a second pipe body coupled with the first pipe body inside the first pipe body, wherein the second pipe body is formed of a second metal material having a different physical property from a physical property of the first metal material, and the second pipe has at least one or more ridges formed on an inner surface of the second pipe; and an inter-

face where the first and second pipe bodies abut each other, wherein a noncontact rate due to a gap present at the interface as defined in Equation 1 satisfies 30% or less:

$$\text{Noncontact rate (\%)} = \frac{L}{2\pi r'} \times 100 \quad [\text{Equation 1}]$$

[0019] where L refers to a sum of lengths of circumferences of gaps present at the interface, and r' refers to a radius of the interface.

[0020] The first metal material is any one of Al, Cu, and an alloy of Al and Cu, and the second metal material is any one of Cu, Ti, SUS, and an alloy of Cu, Ti, and SUS.

[0021] According to the present invention, since different types of metal pipes having different physical properties are coupled with each other with one pipe inserted into the other, physical limits that a single metal pipe might have may be overcome.

[0022] Further, since in addition to formation of protrusions on the outer surface of the compound heat pipe ridges are formed on the inner surface of the compound heat pipe, the area and flow resistance of fluids inside and outside the compound heat pipe may be increased thus maximizing heat transfer capability.

[0023] Further, by properly controlling the noncontact rate due to a gap created at an interface between the outer and inner metal layers of the compound heat pipe, the radial heat transfer rate of the compound heat pipe may be optimized.

[0024] Thus, the compound heat pipe according to the present invention provides advantages, such as light weight and low price, compared to a single type heat pipe made only of copper or a copper alloy as well as excellent corrosion resistance and thermal conductivity compared to a single type heat pipe made only of aluminum or an aluminum alloy. Further, the compound heat pipe according to the present invention provides good heat transfer capability compared to the existing compound heat pipe.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The accompanying drawings illustrating the embodiments of the present invention are provided to make the spirit of the invention understood better together with the detailed description, and it should be understood that the present invention is not limited to those disclosed in the drawings.

[0026] FIG. 1 is a cross section view exaggeratedly illustrating a compound heat pipe in which a plurality of gaps are present at an interface between an outer metal layer and an inner metal layer.

[0027] FIG. 2 is a longitudinal section view illustrating a compound heat pipe according to the present invention.

[0028] FIG. 3 is an expanded view illustrating an interface of a compound heat pipe.

[0029] FIG. 4 is a view for describing a noncontact rate of a compound heat pipe.

[0030] FIG. 5 is a view for describing calculating an average of lengths of circumferences of gaps obtained from a sample of a compound heat pipe.

[0031] FIG. 6 is a graph illustrating a relationship between the noncontact rate and the heat transfer rate.

DESCRIPTION OF THE EMBODIMENTS

[0032] Hereinafter, the embodiments of the present invention will be described with reference to the accompanying drawings. The terms or words used in the specification and claims should not be limited to be construed as usual or dictionary definition but should be rather construed to be consistent with the technical spirits of the present invention based on the principle that the inventors may properly define the terms used in the specification to describe their invention in the best manner.

[0033] Accordingly, it should be understood that the embodiments described in the specification and configurations disclosed in the drawings are merely examples and do not represent all of the technical spirits of the invention and various modifications and variations to the invention and equivalents thereof may be made at the time of the invention.

[0034] First, some terms as used herein are defined.

[0035] As used herein, the term “compound heat pipe” refers to a compound pipe formed by joining at least two or more metal pipes. The metal pipes are made of metals selected to make up for physical weakness between the metals.

[0036] As used herein, the term “noncontact rate” refers to a degree by which the outer metal layer and the inner metal layer are thermally separated from each other due to gaps existent at an interface between the outer and inner metal layers, and is defined as in Equation 1:

$$\text{Noncontact rate (\%)} = \frac{L}{2\pi r'} \times 100 \quad [\text{Equation 1}]$$

[0037] Here, L refers to a sum of lengths of circumferences of gaps present at the interface, and r' refers to a radius of the interface.

[0038] As used herein, the term “heat exchanger” is used to collectively refer to any apparatus with a compound heat pipe, which performs heat exchange through heat transfer between fluids flowing inside and outside the compound heat pipe. Examples of the heat exchanger according to the present invention include absorbers or evaporators for absorption chillers, or evaporators for turbo chillers, heat pump type heat exchangers, and fin tube type heat exchangers.

[0039] As used herein, the term “heat exchanger system” refers to a system that performs heat exchanging operation in an industry facility, room cooling/heating facility, or various mechanical apparatuses using the heat exchanger, and examples of the heat exchanger system include absorption chillers or turbo chillers.

[0040] As used herein, the term “pipe body” refers to a pipe physically treated for conveying a fluid through an inner space thereof.

[0041] FIG. 2 is a longitudinal section view illustrating a compound heat pipe according to the present invention.

[0042] Referring to FIG. 2, a compound heat pipe 20 according to the present invention is a dual pipe that includes a first pipe body 22 and a second pipe body 21 coupled with each other. The second pipe body 21 is inserted into the first pipe body 22 so that an outer surface of the second pipe body 21 is attached onto an inside of the first pipe body 22, and an

interface **23** is provided at points where the first and second pipe bodies **22** and **21** contact each other. Ideally, the first pipe body **22** and the second pipe body **21** are coupled with each other in an airtight sealed manner so that no gaps are created at the interface **23**. However, it is not easy to completely get rid of gaps in a process of separately producing the first pipe body **22** and the second pipe body **21** and then physically coupling each other.

[0043] The first pipe body **22** and the second pipe body **21** are formed of different metals having different physical properties from each other. The first pipe body **22** is made of any one selected from Al or an alloy thereof, Cu or an alloy thereof, and a combination thereof, and the second pipe body **21** is made of any one selected from Cu or an alloy thereof, Ti or an alloy thereof, SUS or an alloy thereof, and a combination thereof.

[0044] A plurality of protrusions **25** are formed on an outer surface of the first pipe body **22** to increase a contact area. Accordingly, it is preferable that the first pipe body **22** have a Young's modulus of 60 to 130 GPa to facilitate to form the protrusions **25**. If the Young's modulus of the first pipe body **22** is less than 60 GPa, it becomes difficult to form a constant angle between an external fin and a surface of the heat pipe so as to improve heat transfer capability when forming the external fin. If the Young's modulus of the first pipe body **22** is more than 130 GPa, it is difficult to smoothly form the protrusions.

[0045] According to embodiments, forming the protrusions on the outer surface of the first pipe body **22** may be performed by processes as disclosed in Korean Patent Application Publication Nos. 2007-63073 and 2009-98526, Korean Patent No. 0518695 and 707682 which are herein incorporated by reference.

[0046] A plurality of ridges **24** are formed on an inner surface of the second pipe body **21** to increase a contact area with a fluid flowing in the second pipe body **21**. To facilitate formation of the ridges **24**, the second pipe body **21** preferably has a Young's modulus of 100 to 200 GPa. If the Young's modulus of the second pipe body **21** is less than 100 GPa, the material becomes too soft to produce the second pipe body **21** to have a desired shape, and if the Young's modulus of the second pipe body **21** is more than 200 GPa, the ridges are difficult to smoothly form.

[0047] According to embodiments, forming the ridges on the inner surface of the second pipe body **21** may be performed by processes as disclosed in Korean Patent Application Publication Nos. 2007-63073 and 2009-98526, Korean Patent No. 0518695 and 707682 which are herein incorporated by reference.

[0048] Formation of the protrusions and ridges on the outer surface of the first pipe body **22** and the inner surface of the second pipe body **21**, respectively, increases an area for heat transfer between the first pipe body **22** and the second pipe body **21** and the fluid, thus increasing the heat transfer efficiency of the heat pipe compared to the conventional compound heat pipes disclosed in Patent Documents 1 to 3.

[0049] As shown in FIG. 2, a compound heat pipe, such as the pipe **20**, according to the present invention has several gaps **30** created at an interface **23** between two different types of metal pipes, where the two pipes are brought in contact with each other.

[0050] FIG. 3 is an expanded view illustrating a gap **30** as obtained by magnifying the gap **30** by 1000 times through a microscope. Referring to FIG. 3, the gap **30** is an irregular slit

extending long along a circumference of the interface **23** and has a distance l' along the circumference (simply referred to as a "circumference length" throughout the specification), a length l between two distal ends (simply referred to as a "straight length" throughout the specification), and a width d in a radius direction (simply referred to as a "radius-directional width" throughout the specification). The radius-directional width d is on the order of about 1 to 10 μm and negligibly small compared to the circumference length l' or the straight length l .

[0051] Since the gap **30** is physically created in the course of inserting the second pipe body **21** into the first pipe body **22**, expanding the pipes, and joining the pipes **22** and **21** to each other, the gap **30** comes to be shaped as an irregular slit that is long with a narrow radius-directional width. Accordingly, an influence by the radius-directional width d of the gap **30** on the heat transfer capability of the compound heat pipe in the radius direction is negligibly low. On the contrary, the circumference length r or the straight length greatly affects the heat transfer capability of the pipe in the radius direction.

[0052] The inventors have modeled a relationship between the circumference lengths of gaps present at the interface **23** and the heat transfer capability (that is, heat transfer rate) of the compound heat pipe in the radius direction as in Equation 1.

[0053] Existence of the gaps present at the interface and affecting the heat transfer rate of the compound heat pipe has been described through a noncontact rate. The noncontact rate represents how much the first pipe body **22** and the second pipe body **21** are spaced apart from each other without physically and/or thermally contacting each other. Accordingly, the noncontact rate being high means that the first pipe body **22** and the second pipe body **21** are thermally spaced apart a lot from each other and the heat transfer rate in the radius direction is resultantly lowered.

[0054] Referring to FIG. 4, a plurality of gaps G1 to G6 are present at the interface **23** of the compound heat pipe **20** having a radius of r' . The gaps G1 to G6 have straight lengths l_1 to l_6 , respectively. A noncontact rate (%) satisfies Equation 1:

$$\text{Noncontact rate (\%)} = \frac{L}{2\pi r'} \times 100 \quad [\text{Equation 1}]$$

[0055] Here, L refers to a sum of circumference lengths of the gaps, and r' refers to a radius of the interface.

[0056] If, as shown in FIG. 4, six gaps are formed at the interface of the compound heat pipe, L satisfies the following:

$$L = l_1 + l_2 + l_3 + l_4 + l_5 + l_6$$

[0057] The circumference length l' of each gap is substantially the same as the straight length l and accordingly is not particularly distinguished from the straight length l .

[0058] The inventors found that the noncontact rate (%) defined in Equation 1 is substantially in inverse proportion to a radial heat transfer rate of the compound heat pipe and the heat transfer rate sharply varies at a specific noncontact rate. For example, the heat transfer rate significantly changes before and after the noncontact rate is 30%.

[0059] Accordingly, the compound heat pipe according to the present invention is characterized to have a noncontact rate of 30% or less. If the noncontact rate is more than 30%, the heat transfer rate becomes not more than 7,000 W/m²K

and this is not preferable. The lower limit of the noncontact rate is not specifically limited but may not have a negative value. Most ideally, the noncontact rate is 0.

[0060] A dual metal pipe having two metal pipes coupled with each other and having different physical properties has been described as an example of a compound heat pipe according to the present invention, but the present invention is not limited thereto. Accordingly, a triple or quadruple metal pipe may be also adopted for the compound heat pipe according to the present invention within departing from the technical spirit of the present invention.

[0061] A method of manufacturing a compound heat pipe having the afore-described configuration according to the present invention is described.

[0062] First, a first metal pipe for the first pipe body **22** and a second metal pipe for the second pipe body **21** are prepared. Then, the second metal pipe is inserted into an internal space of the first metal pipe.

[0063] While the second metal pipe remains inserted into the first metal, heat applies to make the pipes soft, and a drawing process of passing the pipes through a frame having a predetermined diameter is performed to produce a bare tube with a desired shape and outer diameter. When the bar tube is produced, size and level of gaps created at the interface are determined.

[0064] A helix type core is inserted into the inside of the thusly produced bare tube and three rollers are positioned at an outside of the bare tube to form protrusions. Under this circumstance, the bar tube is rotated at a constant speed while being pulled. Accordingly, helix type ridges having the same shape as the core are formed on the inner surface of the bare tube and plural protrusions are formed on the outer surface of the bare tube. By doing so, a compound heat pipe having a first pipe body **22** and a second pipe body **21** as shown in FIG. 2 is complete.

[0065] Hereinafter, a relationship between the noncontact rate (%) and heat transfer rate of a compound heat pipe is described through an experiment.

[0066] 1. Production of Compound Heat Pipe

[0067] A copper pipe having an outer diameter of 19.05 mm and a thickness of 0.5 mm and an aluminum pipe having an outer diameter of 21.5 mm and a thickness of 1 mm were prepared. The copper pipe is inserted into the aluminum pipe so that the copper pipe passes through the aluminum pipe and then the pipes were subjected to an expanding process, thus producing a bare tube. Then, a process of forming ridges on an inner surface of the bare tube and a process of forming protrusions on an outer surface of the bare tube were simultaneously performed on the bare tube, thus completing a plurality of compound heat pipe samples. The number and size of gaps formed at the interface were adjusted by applying different pressing forces in the expanding process or by controlling a pressing force in the ridge or protrusion formation process. By doing so, eleven compound heat pipe samples were produced, and the noncontact rate and heat transfer rate were measured on each sample.

[0068] 2. Calculation of Noncontact Rate (%)

[0069] Each of the produced compound heat pipe samples was cut at a center and both ends thereof as shown in FIG. 5, and the cut interface was observed through an SEM (Scanning Electron Microscope) and the straight lengths of all of the gaps were measured. By summing the measured straight lengths, total sums L1, L2, and L3 of circumference lengths of the gaps at the center and both ends, respectively, were calculated. Then, an average value Lavg of the total sums L1, L2, and L3 were calculated and substituted in Equation 1, thus

producing a noncontact rate (%). For more accuracy, three or more cut portions (including the center and both ends) may be subjected to measurement.

[0070] 3. Measurement of Heat Transfer Rate

[0071] As the heat transfer rate, an overall heat transfer coefficient defined as “U” is calculated. For this purpose, a heat exchanger experiment device is used that may provide the same coolant environment as a chiller. A calorie (Q) is calculated based on a measured saturation temperature of a coolant conducting heat exchanger in the heat exchanger experiment device and a measured temperature, at an inlet and outlet, of water heat exchanging with the coolant. By substituting the calculated calorie, a surface area A of the heat pipe, and a logarithmic mean temperature difference ΔT_{LMTD} in Equation 2, the overall heat transfer coefficient U is obtained:

$$\Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)} \quad (1)$$

$$U = \frac{Q}{A \Delta T_{LMTD}} \quad (2)$$

[0072] Here, Q refers to a calorie [kW] by which the coolant and water heat exchanges each other, ΔT_1 refers to a temperature of the coolant at the inlet (condensation pipe) or a temperature of cooling water at the inlet (evaporation pipe), ΔT_2 refers to a temperature of the coolant at the outlet (condensation pipe) or a temperature of cooling water at the outlet (evaporation pipe), ΔT_{LMTD} refers to a logarithmic mean temperature difference, and A refers to a surface area of the heat pipe.

[0073] 4. Relationship Between Noncontact Rate and Heat Transfer Rate

[0074] The following Table 1 summarizes noncontact rates and heat transfer rates obtained by the above process for eleven compound heat pipe samples.

Noncontact rate (%)	Heat transfer rate [W/m ² K]
0.0	7923
5.0	7815
10.4	7753
14.8	7503
20.1	7214
25.3	7167
30.3	6926
35.2	5279
40.7	3561
44.9	2938
51.6	1750

[0075] The graph in FIG. 6 represents a mutual relationship between the noncontact rate (%) and heat transfer rate based on the results in Table 1.

[0076] Referring to FIG. 6, when the noncontact rate of the compound heat pipe is 0, a highest heat transfer rate in a radial direction is obtained. However, as the noncontact rate of the compound heat pipe increases, the heat transfer rate slowly decreases with a slope of S1 and since the noncontact rate (%) reaches 30%, the heat exchange rate sharply decrease with a slope of S2. For example, the moment the noncontact rate (%) reaches 30% may correspond to an inflection point.

[0077] Accordingly, it may be identified that the heat transfer rate of the compound heat pipe may be optimized by properly adjusting the thickness of the first and second pipe bodies, pressing forces exerted when expanding the first and second pipes, and pressure applied when forming the ridges or protrusions so that the noncontact rate (%) is not more than 30%.

[0078] The compound heat pipe may be designed to have a noncontact rate of 5.0% to 25.3%.

[0079] The compound heat pipe according to the present invention may apply to all types of heat exchangers using heat pipes, such as absorbers or evaporators for absorbing chillers or evaporators for turbo chillers. A heat exchanger system may be established by using a heat exchanger according to the present invention for industry facilities, home cooling/heating facilities, or various mechanical apparatuses. Representative examples include absorbing chillers or turbo chillers.

[0080] As such, the compound heat pipe according to the present invention may overcome physical limits, which a single metal pipe might have, by integrally joining different metal pipes having different physical properties, forming ridges on an inner surface thereof of the pipe and protrusions on an outer surface thereof and may first increase heat transfer capability by increasing the heat transfer area between the pipe and fluid. Further, the compound heat pipe according to the present invention may secondly increase the heat transfer capability by setting the noncontact rate to be 30% or less so that the heat transfer rate of the compound heat pipe in the radial direction may be optimized.

[0081] The invention has been explained above with reference to exemplary embodiments. It will be evident to those skilled in the art that various modifications may be made thereto without departing from the broader spirit and scope of the invention. Further, although the invention has been described in the context its implementation in particular environments and for particular applications, those skilled in the art will recognize that the present invention's usefulness is not limited thereto and that the invention can be beneficially utilized in any number of environments and implementations. The foregoing description and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. A compound heat pipe comprising:

a first pipe body having at least one or more protrusions on an outer surface of the first pipe body, wherein the first pipe body is formed of a first metal material;

a second pipe body coupled with the first pipe body inside the first pipe body, wherein the second pipe body is formed of a second metal material having a different physical property from a physical property of the first metal material, and the second pipe has at least one or more ridges formed on an inner surface of the second pipe; and

an interface where the first and second pipe bodies abut each other, wherein a noncontact rate due to a gap present at the interface as defined in Equation 1 satisfies 30% or less:

$$\text{Noncontact rate (\%)} = \frac{L}{2\pi r'} \times 100 \quad [\text{Equation 1}]$$

where L refers to a sum of lengths of circumferences of gaps present at the interface, and r' refers to a radius of the interface.

2. The compound heat pipe of claim 1, wherein the noncontact rate satisfies 5.0% to 25.3%.

3. The compound heat pipe of claim 1, wherein the first pipe body has a Young's modulus of 60 to 130 GPa and the second pipe body has a Young's modulus of 100 to 200 GPa.

4. The compound heat pipe of claim 1, wherein the first metal material is Al or an alloy of Al.

5. The compound heat pipe of claim 4, wherein the first pipe body has a Young's modulus of 60 to 130 GPa.

6. The compound heat pipe of claim 4, wherein the second metal material is any one of Cu, an alloy of Cu, Ti, an alloy of Ti, SUS, and an alloy of SUS.

7. The compound heat pipe of claim 6, wherein the second pipe body has a Young's modulus of 100 to 200 GPa.

8. The compound heat pipe of claim 1, wherein the first metal material is Cu or an alloy of Cu.

9. The compound heat pipe of claim 8, wherein the first pipe body has a Young's modulus of 60 to 130 GPa.

10. The compound heat pipe of claim 8, wherein the second metal material is any one of Ti, an alloy of Ti, SUS, and an alloy of SUS.

11. The compound heat pipe of claim 10, wherein the second pipe body has a Young's modulus of 100 to 200 GPa.

12. The compound heat pipe of claim 1, wherein the first metal material is any one of Al, Cu, and an alloy of Al and Cu, and the second metal material is any one of Cu, Ti, SUS, and an alloy of Cu, Ti, and SUS, and wherein the first pipe body has a Young's modulus of 60 to 130 GPa, and the second pipe body has a Young's modulus of 100 to 200 GPa.

13. A heat exchanger comprising the compound heat pipe of claim 1.

14. A heat exchanger system comprising the heat exchanger of claim 13, wherein the heat exchanger system performs heat exchange.

15. A method of manufacturing a compound heat pipe comprising:

producing a bare tube by inserting a second metal pipe for a second pipe body into a first metal pipe for a first pipe body and then performing an expanding process; and

pulling the bare tube while rotating the bare tube with a helix type core inserted into the bare tube for forming ridges and a roller positioned outside the bare tube for forming protrusions, wherein a pressing force when performing the expanding process and a pressure when forming the ridges and protrusions are adjusted so that a noncontact rate defined in Equation 1 is not more than 30% due to a gap present at an interface where the first and second pipe bodies abut each other:

$$\text{Noncontact rate (\%)} = \frac{L}{2\pi r'} \times 100 \quad [\text{Equation 1}]$$

where L refers to a sum of lengths of circumferences of gaps present at the interface, and r' refers to a radius of the interface.

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