INTERCONNECTED MICROCHANNEL TUBE

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ABSTRACT

The invention relates to a microchannel tube for use in a heat transfer system. The microchannels have openings in the partitions that separate them from each other, thereby creating many short interconnected passages through which a heat transfer medium will flow in a laminar manner. This permits the liquid and vapor phases of the medium to mix, thereby increasing the efficiency of the system.
INTERCONNECTED MICROCHANNEL TUBE
CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation-in-part of U.S. application Ser. No. 10/303,717, filed Nov. 26, 2002, the entire content of which is expressly incorporated herein by reference.

FIELD OF INVENTION

[0002] The present invention relates to an interconnected microchannel tube for use in a heat transfer device such as an automobile or residential or commercial air conditioning heat exchangers. The microchannel tubes are interconnected to facilitate re-mixing of the vapor-liquid phases and improve the efficiency of the heat exchanger.

BACKGROUND OF THE INVENTION

[0003] Microchannel tubes have been used in recent years in automotive air conditioning units and in residential or commercial air-conditioning heat exchangers. In use, a refrigerant flows through the multiple channels inside a tube. The refrigerant evaporates and condenses as it passes through the tubes, absorbing and releasing heat as it changes phases between liquid and vapor. U.S. Pat. Nos. 4,998,580 and 5,372,188 ("the "188 patent") disclose condensers having small hydraulic diameter flow paths, i.e., microchannels.

[0004] The microchannel tubes currently in use have channels that are isolated from each other, such that each channel works independently from the others when transferring heat. This creates a heat transfer imbalance between the front end of the tube and the leeward side of the tube, in lieu of the flow direction of the external heat transfer medium. The "188 patent is limited in its scope as it requires the hydraulic diameter to be in the range of about 0.015 to 0.07 inches, where the hydraulic diameter is defined as the cross-sectional area of each of the flow paths multiplied by 4 and divided by the wetted perimeter of the corresponding flow path.

[0005] U.S. Pat. No. 6,253,840 to Kuroyanagi discloses a refrigerant evaporator that includes passages defined by partitions. Within the partitions are refrigerant guide members within the partition walls to guide the refrigerant downstream to permit mixing of the vapor and liquid phases. The guide members are located within openings in the partition walls and guide the refrigerant in a downstream direction. The height of the partitions in Kuroyanagi is 2.0 mm, while the openings in the walls have a width (d in FIG. 7) of 1.5 mm and a length of 5 mm. This is the size of a group of about 5 openings. Thus, the area of each group of 5 openings is 7.5 mm². FIG. 10 shows a number of different arrangements for the openings. The arrangement with the fewest openings (other than the one with zero) is sample (2). Sample 2 indicates that the openings are spaced 5 mm apart or "the interval between the respective louver groups is increased to be approximately equal to the length (5 mm) of the respective louver groups." Column 8, lines 10-13. The patent is clear that this is the specified spacing of the louver groups. Thus, for a partition with a length of 20 mm (as shown in FIG. 10), the area of the partition wall would be 100 mm² (20 mm length x 5 mm height). There would be two groups of the 5 mm long openings with 5 mm between them and 5 mm between the edge of the partition and each group of openings. Although the open area of the partitions was not discussed, it can be calculated as an area of 15 mm² or 30% of the area of the partition sidewall. No matter what length the sidewall is, the area of the openings will always be greater than 25% of the area of the partition sidewalls, and generally is greater than 35%. These openings would create undesirably large pressure drops and create turbulent flow in the heat transfer medium. This turbulence is exacerbated by the guide members or louveres present in Kuroyanagi's partitions.

[0006] U.S. Pat. No. 6,247,529 to Shimizu et al. discloses a refrigerant tube for a heat exchanger. The tube has upper and lower walls with the wall portions containing communication holes. Shimizu et al. do not include a plurality of partitions formed of a single sheet in their tube construction. Shimizu et al. do not form serpentine partitions from their heat transfer tubes and instead describe a heat transfer tube with partitions comprised of multiple pieces. Thus, construction of the Shimizu et al. tube is relatively complex.

[0007] Thus, there is a need for improved, simpler heat transfer designs for heat exchangers that include microchannel tubes in order to improve the heat transfer efficiency and to balance heat transfer more uniformly across the entire width of the tubes. The present invention now provides such improvements.

SUMMARY OF THE INVENTION

[0008] The invention relates to a heat transfer tube comprising a sheath surrounding a plurality of partitions forming microchannels wherein through which the heat transfer medium can flow. The partitions advantageously include sidewalls having a plurality of openings therein, such that the heat transfer medium can flow in a lamellar manner between the microchannels thereby permitting mixing of liquid and vapor phases of the heat transfer medium for improved heat transfer of the tube. The fluid passes between the microchannels without encountering obstructions to minimize turbulence in the fluid.

[0009] The hole openings comprise about 1% to 20% of the area of the partition sidewall, with each partition having from about 5 openings per 25 mm to about 1 opening every 75 mm along the length of the partition. These openings comprise up to about 80% of the height of the sidewall of the partition, and can be round, oval, square, rectangular, or triangular.

[0010] In one embodiment, at least 2 to 12 partitions are present so that at least 3 to 13 microchannels are provided in the tube. Preferably, at least 4 to 8 partitions are present so that at least 5 to 9 microchannels are provided in the tube. The partitions are advantageously formed from a single sheet, preferably one that forms serpentine partitions.

[0011] The sheath and partitions can be formed of a metal, such as aluminum or an aluminum alloy, although copper or a copper alloy is preferred. If desired, fins can be attached to an outer surface of the sheath to assist in transferring heat therefrom.

[0012] Another embodiment of the invention relates to an improvement in a heat exchanger that includes a plurality of microchannels therein and through which a heat transfer
medium flows. The improvement comprises providing a plurality of openings in the microchannels, such that the heat transfer medium can flow in a laminar manner between the microchannels thereby permitting mixing of liquid and vapor phases of the heat transfer medium for improved heat transfer of the tube. The fluid passes between the microchannels without encountering obstructions to minimize turbulence in the fluid.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**[0013]** The invention will be better understood in relation to the attached drawings illustrating preferred embodiments, wherein:

**[0014]** FIG. 1 shows a cross-sectional view of a heat exchanger tube made according to the present invention;

**[0015]** FIG. 2 shows a perspective view of a heat exchanger tube according to the invention; and

**[0016]** FIG. 3 shows a cross-sectional view of the heat exchanger taken along 3-3 of FIG. 1.

**DETAILED DESCRIPTION OF THE INVENTION**

**[0017]** Referring to the drawings, the figures show a heat exchange tube formed of a sheath 10 and microchannels 12 according to the present invention. The heat transfer tube is formed by a plurality of partitions 14 that form a plurality of microchannels 12. A heat transfer medium runs through the microchannels 12. In one embodiment, the invention includes at least about 2 to 12 partitions to form at least about 3 to 13 microchannels. In another preferred embodiment, at least about 4 to 8 partitions are present forming at least about 5 to 9 microchannels in the sheath.

**[0018]** The microchannels 12 define a path through which the heat transfer medium flows. As the heat transfer medium flows through a microchannel, it evaporates or condenses, thereby changing the vapor and liquid content of the composition. The microchannel at the front edge of the tube and the leeward edge of the tube may have different levels of heat transfer, due to external reasons. It is therefore possible that the microchannel located near the front edge of the tube has a much greater amount of the vapor phase (or liquid phase) than the microchannel located near the leeward edge. It is therefore necessary to design the microchannels to mix these phases evenly across the microchannels over the entire width of the tube in order to optimize two-phase flow heat transfer. It has now been discovered that apertures or openings between the channels assists and enables the gaseous phase and liquid phase to be uniformly mixed and distributed across all the microchannels in a tube to enhance heat transfer.

**[0019]** The openings or holes 20 in the partitions 14 may be of any shape, such as a polygon such as a slot, rectangle, square, or triangle, but the preferred shape is a circle or oval as these have no sharp edges that could act as stress raisers in the structure. When polygons are used, it is preferred for the corners to be rounded to avoid acting as stress raisers in the apparatus. The openings 20 permit the liquid and vapor to mix and change phase at the same time thereby equalizing the liquid and vapor flow. This mixing will permit the individual heat transfer tube to be about 30% to 50% more efficient than a comparable tube without the openings 20 in the partitions 14. A heat exchanger constructed with a plurality of such tubes would be about 10% to 30% more efficient than conventional heat exchangers.

**[0020]** As noted above, the openings in the partition sidewalls preferably comprise between about 1% to 20% of the area of the partition sidewall. This smaller area of the openings is necessary to keep the mixing of the vapor and liquid phases of the heat transfer medium from becoming too vigorous. This permits the flow to remain in the laminar range, as turbulent flow causes a pressure drop that is too large and may affect the efficiency of the system. It is believed that the area of holes that are greater than about 30 to 40% would create turbulent flow that would create an undesirably large pressure drop. The use of internal baffles, louvers or other internal protuberances to direct the flow of the fluid downstream causes additional turbulence.

**[0021]** The present invention also relates to a heat transfer tube that includes a sheath surrounding a plurality of partitions formed from a single metal sheet, the partitions forming microchannels therein through which a heat transfer medium can flow in a laminar manner, the partitions including sidewalls having a plurality of openings therein, with the openings comprising about 1% to 20% of the area of the partition sidewall such that the heat transfer medium can flow between the microchannels thereby permitting mixing of liquid and vapor phases of the heat transfer medium for improved heat transfer of the tube.

**[0022]** The smaller area of the present openings is necessary to keep the mixing of the vapor and liquid phases of the heat transfer medium from becoming too vigorous. This permits the flow to remain in the laminar range, as turbulent flow causes a pressure drop that is too large and may affect the efficiency of the system. The present invention, the goal is to avoid turbulent flow and instead keep the flow in the laminar regime, and this is achieved by the smaller area of the openings and the omission of guide members or louvers.

**[0023]** The mixing of the gaseous and liquid phases of the heat transfer medium is important to this efficiency, but the mixing cannot be too vigorous. It is generally desirable to keep the flow within the laminar regime, as turbulent flow also causes a pressure drop that is too large that may affect the efficiency of the system.

**[0024]** To further avoid such turbulent flow, the holes should not contain louvers or any other type of protrusion or obstruction extending from the openings or otherwise provided in the microchannels. In this way, the fluid flow is not directed or disturbed, but can simply mix smoothly with the gas in the tubes. The fluid passes between the microchannels without encountering obstructions, such as louvers or other protrusions.

**[0025]** The holes may be of various sizes, but are generally not larger than 80% of the height of the partition, and may even be up to about 50% of the height. The width of the hole is generally no larger than its height. As a typical height of a partition is about 2 mm, the maximum size hole would be a square that is about 1.6 mm by about 1.6 mm. A circular hole having a diameter of about 1.5 mm is usable as would be an oval having a larger diameter of 1.5 mm and a smaller diameter of 1 mm or even of 0.5 mm, with the larger diameter arranged to span the height of the partition. Along
the length of the tube, there are typically from about 5 holes per each 25 mm in length up to about one hole every 75 mm in length, and preferably 2 holes per 25 mm in length to 1 hole for each 50 mm in length. There is no criticality in the placement of the holes and they can be arranged in a uniform fashion or in a staggered or offset arrangement. The holes are simply cut out of the partition wall and preferably remove about 1% to 20% of the wall area of each partition. In a more preferred embodiment, the holes remove about 5% to 10% of the wall area. In yet another embodiment, the holes remove about 1% to 15% of the wall area. The area between the holes must be large enough to not detract from the mechanical strength of the tube and its ability to support the pressure of the flowing heat transfer medium therein.

[0026] The area is calculated by simply multiplying the length of the tube by its height to determine the wall area, and by multiplying the length of the opening by its height (for a square or rectangular opening) to determine the area for an individual opening. That number is then multiplied by the number of openings along the length of the wall. Finally, the total area of the openings is divided by the wall area.

[0027] For example, for a tube with a length of 250 mm and a height of 2 mm with 20 circular openings each having a diameter of 1.5 mm, the percentage of the area of the walls taken up by the holes is calculated as follows:

\[
\text{area of wall}=250 \text{ mm} \times 2 \text{ mm}=500 \text{ mm}^2
\]

\[
\text{area of openings}=\pi (0.75 \text{ mm})^2 = 1.767 \text{ mm}^2 \times 20 = 35.343 \text{ mm}^2
\]

\[
\text{0.030} \quad 35.343 \text{ mm}^2 / 500 \text{ mm}^2 = 7.07\%
\]

[0031] Thus, in this example, the openings remove about 7% of the area of the sidewalls.

[0032] The present invention preferably includes partitions formed of a single sheet. This single piece partition is advantageous in that it aids in the ease of construction and assembly of the tube. The tube and partitions are generally formed of sheet metal. While it is possible to form the tube and partitions from an aluminum sheet, it is preferable to form the tube and partitions from a copper or copper alloy sheet. The latter is advantageous as it does not require a cladding layer for brazing as does aluminum. The heat exchange tube may be formed of two pieces, the outer sheath and the inner partitions, which may be corrugated fins. The tube can also be formed by a single piece of metal sheet using a folding process. The holes are simply cut into the inner partition to form the flow paths between the microchannels.

[0033] The sheath 10 and partitions may be constructed of any suitable brazable material known to those of ordinary skill in the art, such as metals, alloys, or even composites. As noted above, preferred materials include copper and copper alloys or aluminum and aluminum alloys. Typical alloying elements for copper alloys include zinc, tin or nickel. In one embodiment, the tube is a welded thin wall tube made of brass. For convenience, the partitions may be constructed of the same materials as the sheath.

[0034] The partition insert 14 is attached to the sheath 10, generally by brazing with a suitable brazing filler material. For sheaths made of copper and copper alloys, the brazing process may include coating the partitions 14 with braze paste before it is inserted into the sheath 10, or inserting the partitions 14 into the sheath 10 together with a braze foil on each side of the partitions 14 in order to attach the partitions 14 to the sheath 10. The partition insert may be coated with the braze paste by means of a roller. A preferred brazing alloy is a copper-nickel-tin-phosphorus alloy, such as OKCu600, which is commercially available. OKCu600 comprises about 1% to 5% nickel, about 15% to 20% tin, about 4% to 7% phosphorus, and the balance copper. It is not necessary to add flux to this braze material, since phosphorus acts as a flux, making the copper-nickel-tin-phosphorus a self-fluxing alloy. The resulting joint and construction also has better corrosion properties since no flux is present. Also, clean-up is facilitated as there is no flux residue to remove.

[0035] For constructions of aluminum or aluminum alloys, the inside of the sheath 10 has a clad layer, while the partition 14 is uncladded. Alternatively, a cladding layer may be used on the partition 14, rather than on the inside of the sheath 10. This cladding enhances the brazing operation.

[0036] If desired, fins 16 may be attached to the outer surface of the sheaths 10 and run between the sheaths 10 to facilitate the conduction of heat away from the sheath 10, and to provide additional surface area for convective heat transfer by air flowing over the heat exchanger. The sheaths may be coated by rolling or spraying with a brazing material to facilitate adhesion of the fins 16. OKCu600 is a preferred brazing material for copper or copper alloy sheaths. For sheaths 10 made of aluminum or aluminum alloy, either the outside of the sheath 10 or the fins 16 should be clad to permit adhesion to the sheath. The clad layer melts during brazing and with the help of flux, creates a brazed joint.

[0037] A plurality of tubes may be joined to form a heat exchanger. The heat exchanger includes a header at each end of the plurality of tubes. The headers may be formed of the same material as the tubes and insert. In one embodiment, the headers are formed of copper or copper alloy and are slotted to collect the tubes. The fins are inserted between the tubes during the assembly process. The headers are pasted with a brazing paste, capped with pasted caps, and pipes are inserted if necessary and pasted with brazing paste at the joint.

[0038] The configuration of the microchannels with holes therebetween permits the refrigerant to pass between the channels to improve the heat distribution and performance. It basically increases the flow path of the heat transfer medium causing it to become more circuitous. The microchannels actually form many short interconnected passages through which the medium will flow. In this way, the liquid and vapor phases of the medium are more evenly mixed across the tube width thereby enhance the heat transfer of the heat exchanger and increase the energy efficiency of the system.

[0039] The brazing application generally takes place in a furnace. One concern during the process is to prevent oxidation of the tube or the brazing material. The furnace should have a dew point of less than about −40° C. and an oxygen content of less than about 100 ppm. Often, an inert gas atmosphere is used, such as nitrogen having a dew point of about −65° C. and an oxygen content of about 10 ppm.

[0040] It is to be understood that the invention is not to be limited to the exact configuration as illustrated and described herein. Accordingly, all expedient modifications readily
attainable by one of ordinary skill in the art from the disclosure set forth herein, or by routine experimentation therefrom, are deemed to be within the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A heat transfer tube comprising a sheath formed of copper or a copper alloy and surrounding a plurality of partitions formed from a single metal sheet, the partitions forming microchannels therein through which a heat transfer medium can flow in a laminar manner, the partitions including sidewalls having a plurality of openings therein, with the openings comprising between about 1% to 20% of the area of the partition sidewall such that the heat transfer medium can flow between the microchannels, such that the flow passes between the microchannels without encountering obstructions, thereby avoiding turbulence in the fluid and permitting liquid and vapor phases of the heat transfer medium to mix evenly across the microchannels and entire width of the tube in order to optimize two-phase flow heat transfer through the tube.

2. The heat transfer tube of claim 1, wherein at least 2 to 12 partitions are present so that at least 3 to 13 microchannels are provided.

3. The heat transfer tube of claim 1, wherein at least 4 to 8 partitions are present so that at least 5 to 9 microchannels are provided.

4. The heat transfer tube of claim 1, wherein the partition side walls form a plurality of generally V shaped microchannels.

5. The heat transfer tube of claim 1, wherein each partition has from about 5 openings per 25 mm of length to about 1 opening every 75 mm of length along the length of the partition.

6. The heat transfer tube of claim 1, wherein the openings are not larger than about 80% of the height of the sidewall of the partition.

7. The heat transfer tube of claim 1, wherein the openings are round, oval, or polygonal where each corner of the polygon is rounded to avoid acting as stress raisers.

8. The heat transfer tube of claim 7, wherein the sheet forms serpentine partitions.

9. The heat transfer tube of claim 1, wherein the partition sidewalls are formed of copper or a copper alloy.

10. The heat transfer tube of claim 1, further comprising fins attached to an outer surface of the sheath to assist in transferring heat therefrom.

11. A heat exchanger comprising two opposing headers and a plurality of the heat transfer tubes according to claim 1 extending between the headers.

12. A heat exchanger comprising two opposing headers and a plurality of the heat transfer tubes between the headers, wherein each heat transfer tube of the plurality comprises a sheath formed of aluminum or an aluminum alloy and surrounding a plurality of partitions formed from a single sheet of aluminum or an aluminum alloy, with the partitions forming microchannels therein through which a heat transfer medium can flow in a laminar manner, and the partitions include sidewalls having a plurality of openings therein, with the openings comprising between about 1% to 20% of the area of the partition sidewall such that the heat transfer medium can flow between the microchannels, such that the flow passes between the microchannels without encountering obstructions, thereby avoiding turbulence in the fluid and permitting liquid and vapor phases of the heat transfer medium to mix evenly across the microchannels and entire width of the tube in order to optimize two-phase flow heat transfer through the tube.

13. The heat exchanger of claim 12, wherein each heat transfer tube of the plurality has at least 2 to 12 partitions are present so that at least 3 to 13 microchannels are provided.

14. The heat exchanger of claim 12, wherein each heat transfer tube of the plurality has at least 4 to 8 partitions so that at least 5 to 9 microchannels are provided.

15. The heat exchanger of claim 12, wherein each partition has from about 5 openings per 25 mm of length to about 1 opening every 75 mm of length along the length of the partition.

16. The heat exchanger of claim 12, wherein each partition of the heat transfer tubes of the plurality has openings are not larger than about 80% of the height of the sidewall of the partition.

17. The heat exchanger of claim 12, wherein the openings of each heat transfer tube partition of the plurality are round, oval, or polygonal where each corner of the polygon is rounded to avoid acting as stress raisers.

18. The heat exchanger of claim 12, wherein the sheets used to form each partition of the heat transfer tubes of the plurality form serpentine partitions.

19. The heat exchanger of claim 12, wherein the sheets used to form each partition of the heat transfer tubes of the plurality are folded to a plurality of generally V shaped microchannels.

20. The heat exchanger of claim 12, wherein the each heat transfer tube of the plurality has fins attached to an outer surface of its respective sheath to assist in transferring heat therefrom.

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