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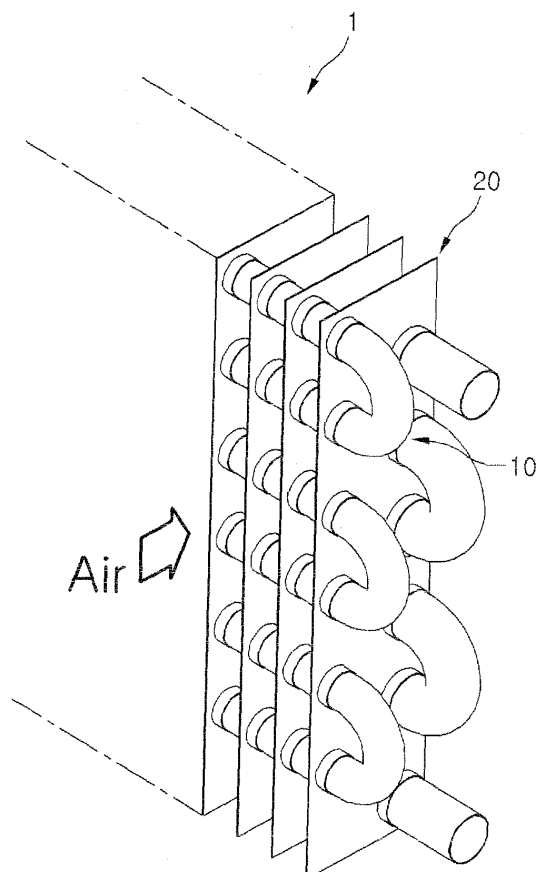
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(54) **Heat exchanger**

(57) A heat exchanger is provided. The heat exchanger includes at least one fin provided with a plurality of slits and a plurality of refrigerant tubes penetrating the fin. The refrigerant tubes include at least one front line tube and at least one rear line tube having a different diameter from the front line tube with reference to a fluid flow direction. The slits include at least one front line slit and at least one rear line slit having a difference width with reference to the fluid flow direction (Fig. 1).

FIG. 1



EP 2 141 430 A2

Description

[0001] The present disclosure relates to a heat exchanger.

[0002] Generally, a heat exchanger is designed such that an internal refrigerant is heat-exchanged with external fluid. The heat exchangers may be classified into fin-tube type heat exchangers and micro channel tube type heat exchangers.

[0003] The fin-tube type heat exchanger includes a plurality of fins and a plurality of refrigerant tubes penetrating the fins. The external fluid (e.g., air) flows between the fins, in the course of which the external fluid is heat-exchanged with the refrigerant flowing along the tubes.

[0004] The refrigerant tubes may include a plurality of front line tubes and a plurality of rear line tubes to enlarge a flow area of the external fluid. The front and rear line tubes are arranged in a zigzag pattern.

[0005] The present disclosure provides a heat exchanger that can improve a heat exchange performance.

[0006] In one embodiment, a heat exchanger includes: at least one fin provided with a plurality of slits; and a plurality of refrigerant tubes penetrating the fin; wherein, the refrigerant tubes include at least one front line tube and at least one rear line tube having a different diameter from the front line tube with reference to a fluid flow direction; and the slits include at least one front line slit and at least one rear line slit having a difference width with reference to the fluid flow direction.

[0007] The details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

[0008] Fig. 1 is a perspective view of a heat exchanger according to a first embodiment.

[0009] Fig. 2 is a cross-sectional view of the heat exchanger of Fig. 1.

[0010] Fig. 3 is a graph illustrating fin efficiencies of a related art heat exchanger and the heat exchanger of Fig. 1.

[0011] Figs. 4 and 5 are graphs illustrating a heat transfer performance and pressure loss in accordance with a width of a fin.

[0012] Fig. 6 is a perspective view of a heat exchanger according to a second embodiment.

[0013] Fig. 7 is a cross-sectional view of the heat exchanger of Fig. 7.

[0014] Fig. 8 is a cross-sectional view of a heat exchanger according to a third embodiment.

[0015] Fig. 9 is a graph illustrating a pressure loss in accordance with a rear line slit in a last line and a rear end of a fin.

[0016] Fig. 10 is a graph illustrating a pressure loss in accordance with a distance between a center of a rear line tube and an adjacent rear line slit.

[0017] Reference will now be made in detail to the embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings.

[0018] In the following detailed description of the preferred embodiments, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific preferred embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is understood that other embodiments may be utilized and that logical structural, mechanical, electrical, and chemical changes may be made without departing from the spirit or scope of the invention. To avoid detail not necessary to enable those skilled in the art to practice the invention, the description may omit certain information known to those skilled in the art. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims.

[0019] Fig. 1 is a perspective view of a heat exchanger according to a first embodiment and Fig. 2 is a cross-sectional view of the heat exchanger of Fig. 1.

[0020] Referring to Figs. 1 and 2, a heat exchanger of a first embodiment includes a plurality of refrigerant tubes 10 along which fluid flows and a plurality of fins 20 penetrating the refrigerant tubes 10.

[0021] In more detail, the refrigerant tubes 10 include a plurality of front line tubes 11 that are located at a front side with reference to a fluid flow direction and a plurality of rear line tubes 12 that are located at a rear side with reference to the fluid flow direction.

[0022] The front line tubes 11 are spaced apart from each other at predetermined intervals in a perpendicular direction to the fluid flow direction. The rear line tubes 12 are also spaced apart from each other at predetermined intervals in the perpendicular direction (an up-down direction in Fig. 2) to the fluid flow direction.

[0023] The front line tubes 11 and the rear line tubes 12 are arranged in a zigzag pattern relative to each other. That is, each of the front line tubes 11 is located between two rear line tubes 12.

[0024] The fins 20 are spaced apart from each other at predetermined intervals. The front and rear line tubes 11 and 12 penetrate each of the fins 20.

[0025] Meanwhile, a diameter D1 of the front tube 11 is less than a diameter D2 of the rear line tube 12 so that the fluid can effectively pass through the heat exchanger 1.

[0026] In more detail, a part of the fluid introduced from the front side of the front line tubes 11 into spaces between the fins 20 passes around the front line tubes 11 and is then discharged to a rear side of the rear line tubes 12. A part of the fluid stays at a rear side adjacent to the front line tubes 11.

[0027] Here, the area where the fluid stays at the rear side of the front line tubes 11 is referred to as a wake area W. As an amount of the fluid staying at the wake area W increases or the wake area W increases, the fluid cannot effectively flow.

[0028] Accordingly, in the embodiment, the front line

tube 11 is designed such that a diameter thereof is less than a diameter of the rear line tube 12 so that the amount of the fluid staying at the wake area W or the wake area W can be reduced and thus the fluid can effectively flow.

[0029] When the airflow can be effectively realized as described above, the heat exchange between the fluid and the refrigerant can be effectively realized and thus the heat exchange performance of the heat exchanger can be improved.

[0030] At this point, a ratio between the diameter D1 of the front line tube 11 and the diameter D2 of the rear line tube 12 is set to satisfy the following:

[0031]

$$1: 1.1 \sim 1.5$$

[0032] Here, when the ratio between the diameter D1 of the front line tube 11 and the diameter D2 of the rear line tube 12 is less than 1.1 (i.e., when the diameter D1 of the front line tube 11 is almost same as the diameter D2 of the rear line tube 12), it is difficult to achieve the reduction of the amount of the fluid at the wake area W. When the ratio between the diameter D1 of the front line tube 11 and the diameter D2 of the rear line tube 12 is greater than 1.5, an amount of the refrigerant flowing along the front line tubes 11 is significantly less than the amount of the fluid flowing around the rear line tubes 12 less than 1.1 and thus the heat exchange performance is significantly reduced.

[0033] Meanwhile, when a distance from a front end 20a of the fin 20, which initially meets the fluid with reference to the fluid flow direction to a center of the front line tubes 11 is referred to as L1, a distance from a rear end 20b of the fin 20 to a center of the rear line tube 12 is referred to as L2, and a horizontal distance from the center of the front line tubes 11 and the center of the rear line tubes 12 is referred to as R, the R and L1 is set to satisfy the following:

[0034]

$$R/L1 = 2.0 \sim 2.5$$

[0035] In addition, the R and L2 are set to satisfy the following:

[0036]

$$R/L2 = 1.7 \sim 2.2$$

[0037] Further, in order to reduce an overall size of the heat exchanger 1, the L1 is set to be less than L2 and the L1 and L2 are set to satisfy the following:

[0038]

$$L2/L1 = 1.1 \sim 1.5$$

[0039] In addition, the R, L1, and L2 are set to satisfy the following:

[0040]

$$R = L1 + L2$$

[0041] Accordingly, considering the overall structure of the fins 20, the front fin may be 2L1 and the rear fin may be 2L2.

[0042] Meanwhile, the diameter D1 of the front line tube 11 and the distance L1 from the front end of the fin 20 to the center of the front line tube 11 are set to satisfy the following:

[0043]

$$2L1 - D1 < 4.5 \text{ mm}$$

[0044] Further, the diameter D1 of the front line tube 11 may be set within a range of 4.5-5.5 mm. For example, when the diameter D1 of the front line tube 11 is 5 mm, the 2L1 may be less than 9.5 mm.

[0045] In addition, the diameter D2 of the rear line tube 12 and the distance L2 from the rear end of the fin 20 to the center of the rear line tubes are set to satisfy the following:

[0046]

$$2L2 - D2 < 4.5 \text{ mm}$$

[0047] In addition, the diameter D2 of the rear line tube 12 may be formed within a range of 6.5-7.5 mm. For example, when the diameter D2 is 7 mm, the 2L2 may be set to be less than 11.5 mm.

[0048] According to the above-described embodiment, since the diameter D1 of the front line tube 11 is set to be less than the diameter D2 of the rear line tube 12, the fluid flow resistance by the front line tube 11 is reduced and the wake area in rear of the front line tubes 11 is reduced. Further, as the fluid flow resistance is reduced, an amount of the fluid increases and the fluid flow noise can be reduced.

[0049] Further, since the distance from the front end of the fin 20 to the center of the front line tube 11 is less than the distance from the rear end of the fin 20 to the center of the rear line tube 12, an overall width of the fin is reduced and thus the heat exchanger can be formed

in a more compact design.

[0050] Fig. 3 is a graph illustrating fin efficiencies of a related art heat exchanger and the heat exchanger of Fig. 1 and Figs. 4 and 5 are graphs illustrating a heat transfer performance and pressure loss in accordance with a width of a fin.

[0051] Fig. 4 is a graph illustrating a case when the diameter D1 of the front line tube is, for example, 5 mm, and Fig. 5 is a graph illustrating a case when the diameter D1 of the front line tube is, for example, 7 mm.

[0052] Referring first to Fig. 3, the transverses axis represents a speed of fluid and the longitudinal axis represents fin efficiency. The graph A illustrates a test result using a heat exchanger (a width of the overall fins is 200 mm) where the diameter of the front line tube is 5 mm, the diameter of the rear line tube 7 mm, the width 2L1 of the front line fin 2L1 is 9 mm, and the width 2L2 of the rear line fin is 11 mm.

[0053] The graph B illustrates a test result using a heat exchanger (a width of the overall fins is 22 mm) where the diameter of the front line tube is 7 mm, the diameter of the rear line tube 7 mm, the width 2L1 of the front line fin 2L1 is 11 mm, and the width 2L2 of the rear line fin is 11 mm.

[0054] In the graph B, when it is assumed that the speed of the fluid is 1 m/s and the fin efficiency is 100%, it can be noted that the 2L1 is more reduced than the 2L2. In addition, in the graph A, when the diameter of the front line tube is more reduced than the rear line tube, it can be noted that the fin efficiency increases by 35%.

[0055] Referring to Fig. 4, when it is assumed that the pressure loss and the heat transfer performance are 100% when the width W1 of the front line fin 2L1, the heat transfer performance and the pressure loss are reduced as the width of the front line fin is gradually further reduced from 9 mm. In addition, the variation of the heat transfer performance is very small and the pressure loss increases as the width of the front line fin is gradually further increased from 9 mm.

[0056] Accordingly, when the diameter of the front line tube is 5 mm and the width of the front line fin is approximately 9 mm, the increase of the pressure loss can be prevented while keeping the heat transfer performance.

[0057] Referring to Fig. 5, when it is assumed that the pressure loss and the heat transfer performance are 10% when the width W2 of the rear line fin 2L2 is 11 mm, the heat transfer performance and the pressure loss are reduced as the width W2 of the rear line fin is gradually further reduced from 11 mm and the variation of the heat transfer performance is very small but the pressure loss is increased as the width of the rear line fin is gradually further increased from 11 mm.

[0058] Accordingly, when the diameter of the rear line tube is 7 mm and the width of the rear line fin is approximately 11 mm, the increase of the pressure loss can be prevented while keeping the heat transfer performance.

[0059] In conclusion, when the diameter of the front line tube is designed to be less than the diameter of the

rear line tube, the wake area in rear of the front line tube can be reduced. In addition, when the front line fin is designed to have a greater width than the rear line fin, the heat transfer performance can be kept. Therefore, the overall size of the heat exchanger can be reduced while the heat exchange performance of the heat exchanger is improved.

[0060] Fig. 6 is a perspective view of a heat exchanger according to a second embodiment and Fig. 7 is a cross-sectional view of the heat exchanger of Fig. 7.

[0061] Referring to Figs. 6 and 7, a heat exchanger of a second embodiment includes a plurality of front line tubes 11, a plurality of rear line tubes 12, a plurality of front line fins 30 through which the front line tubes 11 pass, and a plurality of rear line fins 40 through which the rear line tubes 12 pass.

[0062] In more detail, the front line fins 30 and the rear line fins 40 are spaced apart from each other. That is, the front line tubes 11 and the rear line tubes 12 penetrate different fins.

[0063] Further, a diameter D1 of the front line tube 11 is set to be less than a diameter D2 of the rear line tube 12. A ratio between the diameter D1 and the diameter D2 are set to satisfy the following:

[0064]

$$1: 1.1 \sim 1.5$$

[0065] The reason for setting the diameter of the front line tube 11 to be less than the diameter of the rear line tube 12 will not be illustrated as it is already described in the first embodiment.

[0066] Further, a width W1 of the front line fin 30 in a direction in parallel with a fluid flow direction is set to be less than a width W2 of the rear fin 40.

[0067] Further, a ratio between the widths W1 and W2 is set to satisfy the following:

[0068]

$$1: 1.1 \sim 1.5$$

[0069] As described above, as the diameter of the front line tube 11 is set to be less than the diameter of the rear line tube 12 and the width of the front line fin 30 is set to be less than the diameter of the rear line fin 40, the heat exchanger can be more compact.

[0070] Meanwhile, the diameter D1 of the front line tube 11 and the width W1 of the front line fin 30 are set to satisfy the following:

[0071]

$$1.6 < W1/D1 < 2.2$$

[0072] The diameter D1 of the rear line tube 12 and the width W2 of the rear line fin 40 are set to satisfy the following:

[0073]

$$1.4 < W2/D2 < 2.0$$

[0074] Further, the diameter D1 of the front line tube 11 and the width W1 of the front line fin 30 are set to satisfy the following:

[0075]

$$W1-D1 < 4.5 \text{ mm}$$

[0076] Further, the diameter D1 of the front line tube 11 may be set within a range of 4.5-5.5 mm. For example, when the diameter D1 of the front line tube 11 is 5 mm, the width of the front line fin 30 will be 9.5 mm.

[0077] In addition, the diameter D2 of the rear line tube 12 and the width W2 of the rear line fin 40 are set to satisfy the following:

[0078]

$$W2-D2 < 4.5 \text{ mm}$$

[0079] Further, the diameter D2 of the rear line tube 12 may be set within a range of 6.5-7.5 mm. For example, when the diameter D2 of the rear line tube 12 is 7 mm, the width of the rear line fin 40 will be less than 11.5 mm.

[0080] Fig. 8 is a cross-sectional view of a heat exchanger according to a third embodiment.

[0081] The third embodiment is identical to the first embodiment except that a plurality of slits are formed on the fins. Therefore, only the features of the third embodiment will be described hereinafter.

[0082] Referring to Fig. 8, a heat exchanger of this embodiment includes a plurality of front line tubes 11, a plurality of rear line tubes 12, and a plurality of fins 50 through which the front and rear line tubes 11 and 12 pass.

[0083] The fin 50 includes a front line slit portion formed between the front line tubes 11 with reference to a length direction (a perpendicular direction to a fluid flow direction, hereinafter, an up-down direction in Fig. 8) of the fin 50 and a rear line slit portion formed between the rear line tubes 12.

[0084] In more detail, the front line slit portion includes a plurality of front line slits 51 that are arranged in series in a direction in parallel with the fluid flow direction. The

front line slits 51 may be formed in two or more lines. For example, the slits 51 are arranged in four lines in Fig. 8.

[0085] The rear line slit portion includes a plurality of rear line slits 52 that are arranged in series in a direction in parallel with the fluid flow line. The rear line slits 52 may be arranged in three or more lines. In Fig. 8, the rear line slits 52 are arranged in, for example, four lines.

[0086] Further, in order to form the heat exchanger in a compact design, a width w1 of the front slit 51 is set to be same as or less than a width w2 of the rear line slit 52. Further, the width w1 of the front line slit 51 may be formed within a range of 0.8-1.1 mm.

[0087] In addition, the width w1 of the front line slit 51 and the width w2 of the rear line slit 52 are set to satisfy the following:

[0088]

$$0.65 \leq w1/w2 \leq 1$$

[0089] In addition, in order to form the heat exchanger in a compact design, a distance between the front line slits 51 is equal to or less than a distance d2 between the rear line slits 52.

[0090] Further, the distance between the front line slits 51 is equal to or greater than the width w1 of the front line slit 51. The distance d2 between the rear line slits 52 is equal to or greater than the width w2 of the rear line slit 52.

[0091] In addition, the width w1 of the front line slit 51 and the distance d1 between the front line slits 51 are set to satisfy the following:

[0092]

$$0.7 \leq w1/d1 \leq 1.0$$

[0093] Further, the distance d2 between the rear line slits 52 and the width w2 of the rear line slit 52 are set to satisfy the following:

[0094]

$$0.5 \leq w2/d2 \leq 1.0$$

[0095] Further, in order to improve the heat exchange efficiency, a distance A1 from a front end of the fin 50 to the front line slit 51a in the first line of the front line slit portion is set to satisfy the following:

[0096]

$$0.6 \text{ mm} \leq A1 \leq 1.2 \text{ mm}$$

[0097] When considering a temperature of the fluid (air) passing through the heat exchanger, a temperature of the fluid contacting the front end of the fin 50 is relatively low. Accordingly, in order to allow the heat exchange at the front end of the fin 50 to be effectively realized, the front line slits 51a in the first line are formed to be adjacent to the front end of the fin 51 so as to increase a heat exchange area with a low temperature fluid.

[0098] At this point, the A1 is less than 0.6 mm, it is difficult to process the front line slit in the first line and to achieve the boundary layer destruction effect that is a function of the slit. On the other hand, when the A1 is greater than 1.2 mm, the boundary layer of the fluid (air) is not destructed and the fluid flow distance increases. Therefore, the heat exchanger performance is deteriorated as compared with the case where the A1 is less than 1.2 mm.

[0099] Further, in order to allow condensed water that is generated during the passing of the fluid through the heat exchanger to be effectively discharged, a distance A2 from a rear end of the fin 50 to the rear line slit 52a in the last line of the rear line slit portion may be formed within a range of 0.8-1.4 mm.

[0100] In addition, the A1 and A2 are set to satisfy the following:

[0101]

$$0.5 \leq A1/A2 \leq 0.9$$

[0102] Further, in order to allow the condensed water generated during the heat exchange to be effectively discharged, a distance cw from an imaginary line connecting a center C1 of the front line tubes 11 to a center C2 of the rear line tubes 12 to a slit adjacent to the imaginary line is set to be greater than 0.5 mm.

[0103] That is, in Fig. 8, a distance between the front line slit in the second line and the front line slit in the third line is formed to be equal to or greater than 1 mm and a distance between the rear line slit in the second line and the rear line slit in the third line is formed to be equal to or greater than 1 mm.

[0104] Fig. 9 is a graph illustrating a pressure loss in accordance with the rear line slit in the last line and the rear end of the fin.

[0105] In Fig. 9, the transverse axis indicates a distance A1 (mm) between the last line of the rear slits and the rear end of the fin and the longitudinal line indicates the pressure loss. In addition, other test conditions are same as the graph of Fig. 4.

[0106] Here, the condensed water discharge performance varies in accordance with the amount of the pressure loss. That is, when the condensed water is not effectively discharged, the pressure loss increases. When the condensed water is effectively discharged, the pressure loss is reduced.

[0107] Referring to Fig. 9, when the pressure loss is

100% when the A2 is 0.8 mm, the pressure loss increases when the distance L2 is less than 0.8 mm. In addition, when the distance L2 is greater than 0.8 mm, the pressure loss is reduced, in the course of which, when the distance L2 is equal to or greater than 1.4 mm, the pressure loss is constantly maintained.

[0108] Therefore, in order to reduce the size of the heat exchanger and effectively discharge the condensed water, the A2 may be formed within a range of 0.8-1.4 mm.

[0109] Fig. 10 is a graph illustrating a pressure loss in accordance with a distance between a center of the rear line tube and the adjacent rear line slit.

[0110] In Fig. 10, the transverse line indicates two times a distance 2CW(mm) between the center of the rear line tube and the adjacent rear line slit and the longitudinal line indicates the pressure loss. Other test conditions are same as Fig. 9.

[0111] Referring to Fig. 10, when it is assumed that the pressure loss is 100% when the 2CW is 1.0 mm, the pressure loss increases when the 2CW is less than 1.0 mm. In addition, when the 2CW is greater than 1.0 mm, the pressure loss is reduced, in the course of which, when the 2CW is equal to and greater than 1.8 mm, the pressure loss is constantly maintained.

[0112] Therefore, in order to reduce the size of the heat exchanger and effectively discharge the condensed water, the 2CW may be formed within a range of 1.0-1.8 mm.

[0113] Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, various variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of the disclosure, the drawings and the appended claims. In addition to variations and modifications in the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

Claims

1. A heat exchanger comprising at least one fin provided with a plurality of slits; and a plurality of refrigerant tubes penetrating the fin, **characterized in that**, the refrigerant tubes include at least one front line tube and at least one rear line tube having a different diameter from the front line tube with reference to a fluid flow direction; and the slits include at least one front line slit and at least one rear line slit having a difference width with reference to the fluid flow direction.
2. The heat exchanger according to claim 1, wherein the diameter of the front line tube is less than the diameter of the rear line tube; and

the width of the front line slit is less than the width of the rear line slit.

3. The heat exchanger according to claim 2, wherein the front and rear line slits are arranged in a plurality of lines in a direction in parallel with the fluid flow direction.

4. The heat exchanger according to claim 3, wherein the fins and slits are arranged to satisfy the following:

$$0.5 \leq A1/A2 \leq 0.9$$

$$0.6 \text{ mm} \leq A1 \leq 1.2 \text{ mm}$$

where, A1 is a distance from a front end of the fin to the front line slit in a first line with reference to the fluid flow direction; and

A2 is a distance from a rear end of the fin to the rear line slit in a last line.

5. The heat exchanger according to claim 3, wherein a distance between the front line slits is less than a distance between the rear line slits.
6. The heat exchanger according to claim 3, wherein a distance between the front line slits is equal to or greater than a width of the front line slit; and a distance between the rear line slits is equal to or greater than a width of the rear line slit.
7. The heat exchanger according to claim 6, wherein the width of the front line slit and the width of the rear line slit are set to satisfy the following:

$$0.8 \text{ mm} \leq w1 \leq 1.1 \text{ mm}$$

$$0.65 \leq w1/w2 \leq 1.0$$

where, the w1 is the width of the front line slit and the w2 is the rear line slit.

8. The heat exchanger according to claim 6, wherein the diameter of the front line tube, the diameter of the rear line tube, the width of the front line slit, and the width of the rear line slit are set to satisfy the following:

$$0.7 \leq w1/d1 \leq 1.0$$

$$0.5 \leq w2/d2 \leq 1.0$$

where, the d1 is the diameter of the front line tube, the d2 is the diameter of the rear line tube, w1 is the width of the front line slit, and w2 is the width of the rear line slit.

9. The heat exchanger according to claim 1, wherein a distance (cw) from an imaginary line interconnecting the front line tubes or the rear line tubes to the slit adjacent to the imaginary line is equal to or greater than 0.5 mm.
10. The heat exchanger according to any of claims 1 to 9, wherein the front line slits are arranged in two or more lines and the rear line slits are arranged in three or more lines.
11. The heat exchanger according to any of claims 1 to 10, wherein the front and rear line tubes penetrate one fin.
12. The heat exchanger according to any of claims 1 to 11, wherein a ratio between the diameter of the front line tube and the diameter of the rear line tube is 1:1.1~1.5.
13. The heat exchanger according to claim 12, wherein, when a horizontal distance from a front end of the fin to a center of the front line tube is L1, a horizontal distance from a rear end of the fin to a center of the rear line tube is L2, and a horizontal distance from the center of the front tube to the center of the rear line tube is R, a ratio between L1 and R is 1:2.0~2.5 and a ratio between L2 and R is 1:1.7~2.2.
14. The heat exchanger according to claim 1, wherein the fins include at least one front line fin through which the front line tube passes and at least one rear line fin through which the rear tube passes, the rear line tube being separately formed with the front line tube.
15. The heat exchanger according to claim 14, wherein a ratio between the diameter of the front line tube and the diameter of the rear line tube is 1:1.1~1.5, wherein the front and rear line tubes are designed to satisfy the following:

$$1.6 < W1/D1 < 2.2$$

$$1.4 < W2/D2 < 2.0$$

where, the D1 is the diameter of the front line tube, the D2 is the diameter of the rear line tube, the W1 is a width of the front line fin, and the W2 is a width of the rear line fin.

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FIG.1

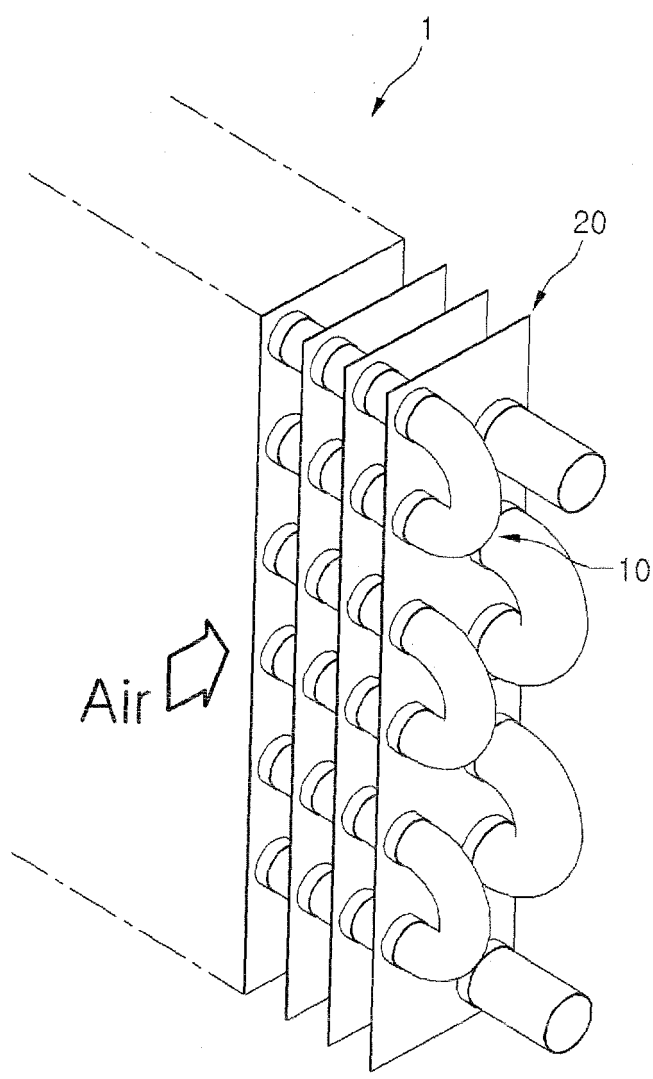


FIG.2

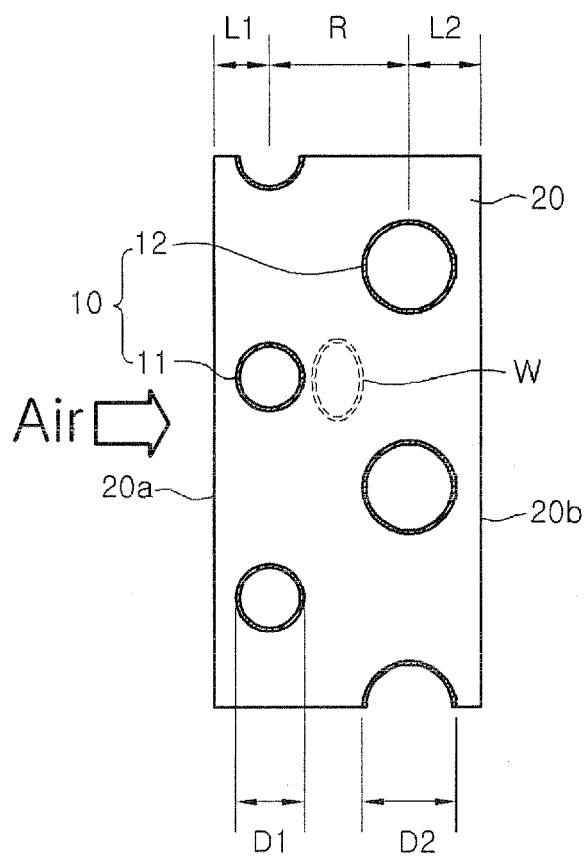


FIG. 3

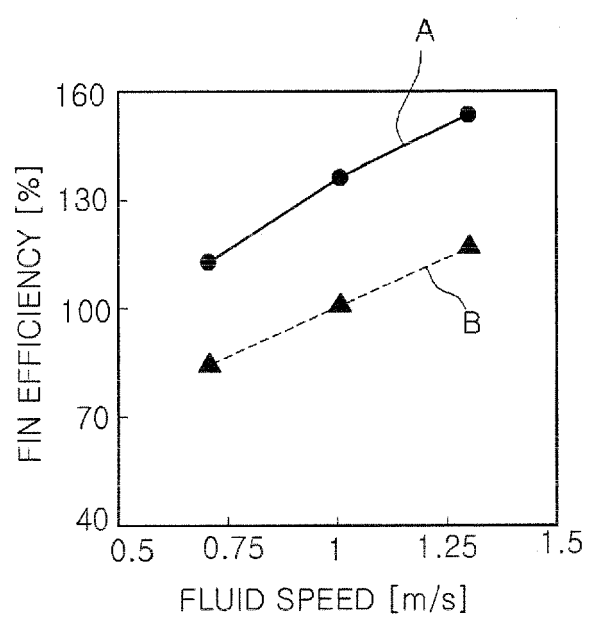


FIG. 4

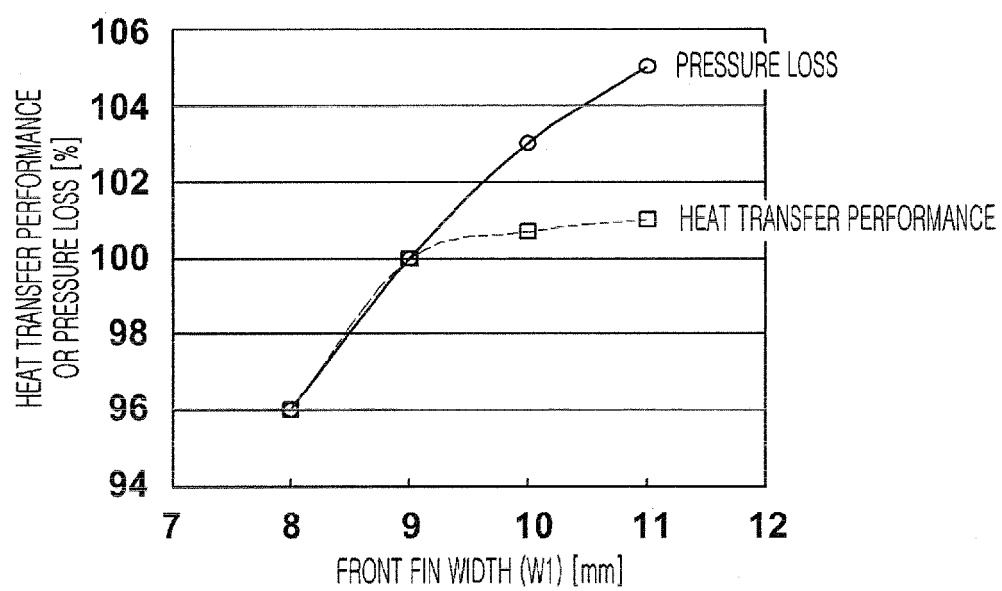


FIG. 5

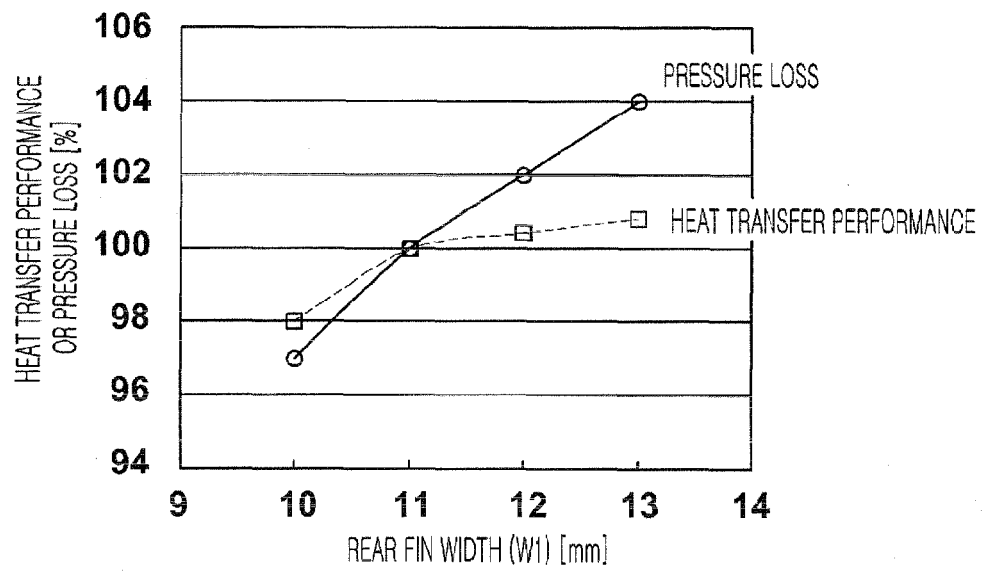


FIG. 6

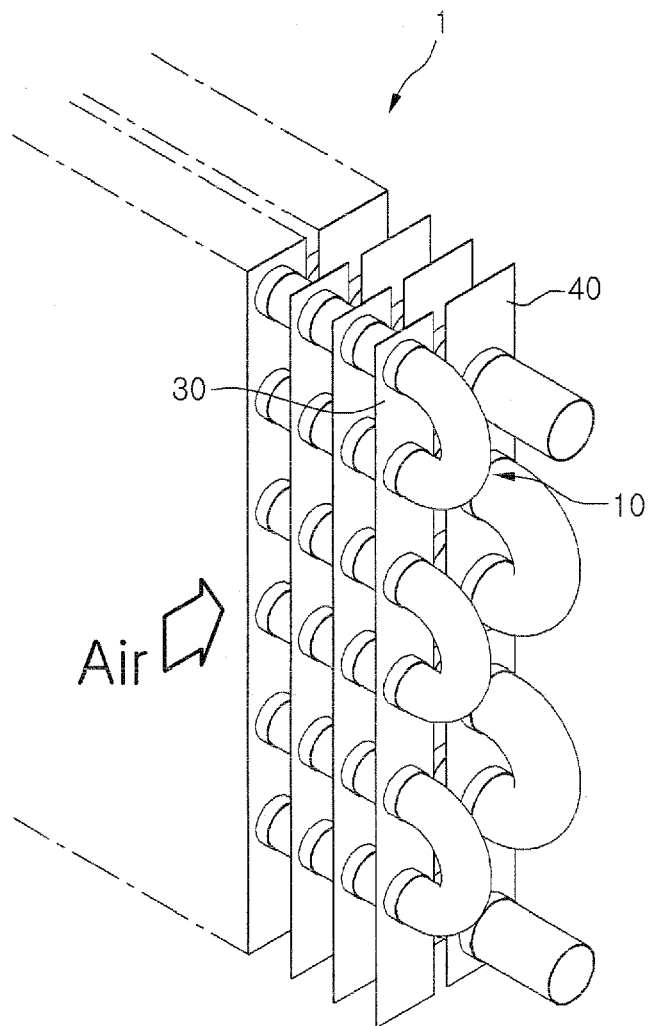


FIG. 7

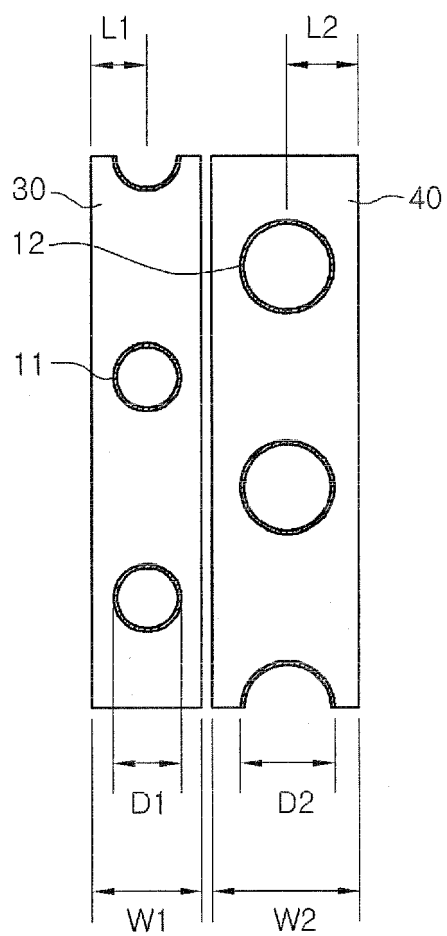


FIG. 8

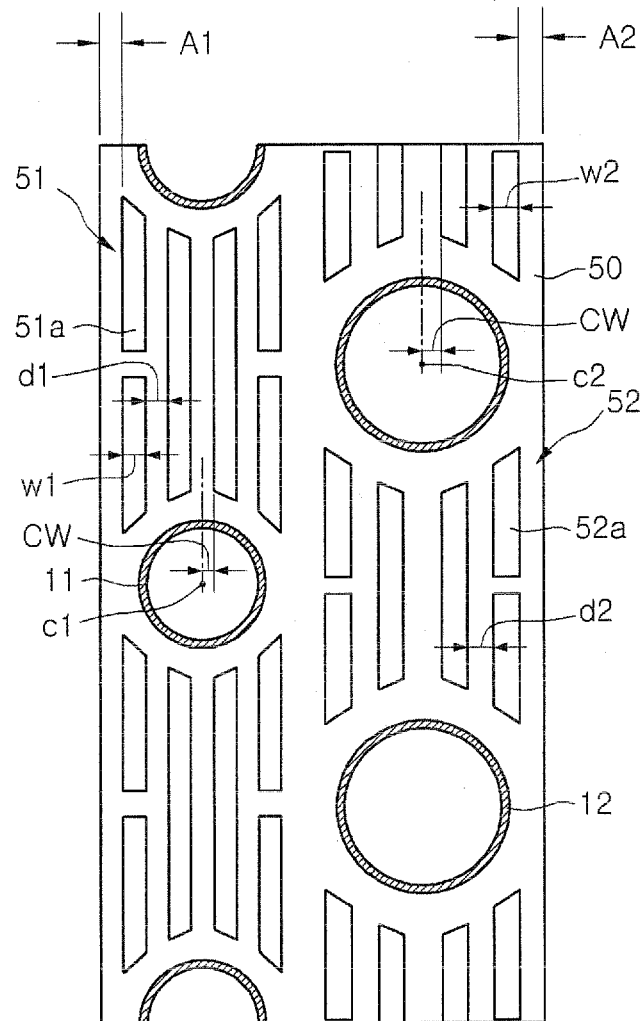


FIG. 9

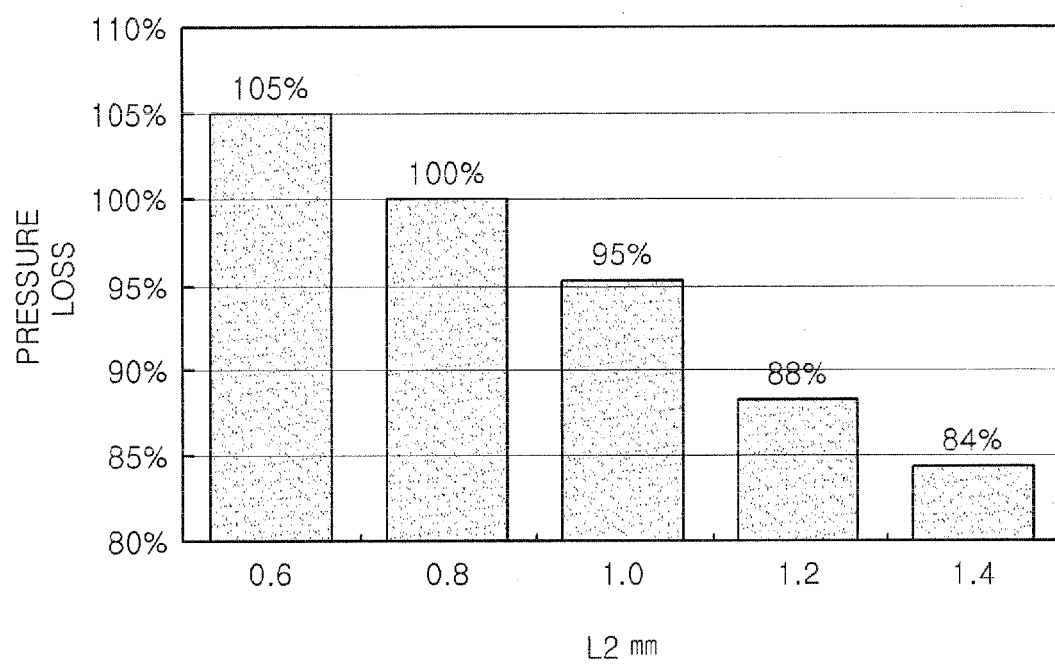


FIG.10

