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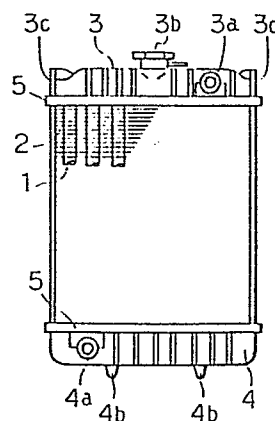
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(54) Solderless heat exchanger.

(57) A solderless heat exchange wherein an admixture of thermally conductive fine powder and fixing agent is applied to the outer periphery (7) of each tube thereof. Ethyl Cello-solve, or a solvent, is added to the admixture to ensure that the admixture is firmly fixed to the outer periphery. Thereafter, the tubes are inserted into holes (2a) formed in fins (2) and then the tubes are expanded to join the tubes (1) to the fins. The use of the admixture accelerates the heat transfer between the tubes and the fins and improves the heat exchange efficiency.

FIG. 1



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TITLE OF THE INVENTION

Solderless Heat Exchanger

BACKGROUND OF THE INVENTION

The present invention relates to heat exchangers
5 of the type in which tubes extending through holes formed in
fins have been joined to the fins by tube expanding process.

Heat exchangers of this kind have been used as
automobile radiators, car heater cores, air conditioning hot
water radiators, etc. The tubes of such heat exchangers are
10 joined to the fins by mechanically expanding the tubes. For
this reason, it can be said microscopically that the tubes
are in contact with the respective fins only in quite small
area. The present inventor and others have found
experimentally that there exist gaps of the order of several
15 microns at the interface of tube and fin due to the
roughness of the surfaces of the fins and tubes and that
these gaps impede heat transfer between the fins and tubes,
thus lowering the heat exchange efficiency.

SUMMARY OF THE INVENTION

20 It is the primary object of the present invention
to provide a radiator which is excellent in heat exchange
efficiency.

This primary objective is achieved by providing a
heat exchanger in which heat transfer between the fins and
25 tubes is improved over that of the conventional heat

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exchanger.

This is accomplished by narrowing the gaps between the fins and the tubes in a favorable way.

In order to narrow the gaps, there is introduced
5 an admixture of thermally conductive fine powder and a
fixing agent into the interface between the fins and tube
within holes in the fins.

There is also provided a method for joining a tube
and fin of a heat exchanger comprising the steps of: forming
10 a mixture of a thermally conductive fine powder and a fixing
agent, applying the mixture to the tube, inserting the tube
into said hole of the fin, and expanding the tube radially
to join the fin to the tube.

BRIEF DESCRIPTION OF THE DRAWINGS

15 Fig. 1 is a front elevation of a heat exchanger
according to the present invention;

Fig. 2 is an enlarged view of the main portion of
the heat exchanger shown in Fig. 1;

Fig. 3 is a diagram for showing the cross-
20 sectional shape of the tubes of the heat exchanger shown in
Fig. 1;

Fig. 4 is a perspective view of one particle of
thermally conductive fine powder; and

Fig. 5 is an enlarged view of a surface at which a
25 tube is contact with a fin.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to Figs. 1 and 2, there is shown a heat exchanger which embodies the concept of the present invention and which is adapted to be used as an automobile radiator. The heat exchanger has tubes 1 and fins 2 provided with holes 2a to receive and fix the tubes 1. Each of the tubes 1 has a thickness of 0.4 mm and is made of an aluminum alloy bearing Japanese Industrial Standard code A 3003-0. Each of the fins 2 has a thickness of 0.1 mm and is made of an aluminum material bearing Japanese Industrial Standard code A 1050-H24. The inside diameter of the holes 2a in the fins 2 is larger than the outside diameter of the tubes 1 which are not yet fixed by approximately 0.3-0.4 mm. After the tubes 1 are inserted into the holes 2a, a tube expanding tool (not shown) is forced into the tubes 1 to expand them. Then, collars 2b which are located at the fringes of the holes 2a are brought into contact with the tubes 1 to secure the tubes in the holes 2a in the fins 2. Header plates 5 made of aluminum are disposed at both ends of the tubes 1 to firmly fix the tubes 1. An upper tank 3 into which the high-temperature coolant discharged from the engine flows is secured by caulking outside one of the header plates 5. A lower tank 4 is secured outside the other header plate 5, and the coolant from the upper tank flows into the tank 4 after it is cooled by exchanging heat

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with the outside air while passing through the tubes 1. The upper tank 3 is molded out of nylon resin and reinforced with glass fibers. An intake pipe 3a for allowing the heated coolant from the engine to flow into the upper tank 3, a water supply pipe 3b for replenishing coolant, and a mounting bracket 3c for mounting the whole heat exchanger in the automobile are molded integrally with the tank 3. The lower tank 4 is molded out of nylon resin in the same manner as the upper tank 3. An exhaust pipe 4a for directing the cooled coolant in the lower tank 4 into the engine, and a mounting bracket 4b for mounting the heat exchanger in the automobile are molded integrally with the tank 4.

Referring next to Fig. 3, the tubes 1 are elliptical in shape. Each ellipsis is defined by connecting together two arcs of different curvatures. Let R_1 be the radius of the smaller arcs, R_2 be the radius of the larger arcs, A be the ellipse major axis, and B be the ellipse minor axis. Then, the relationship

$$R_2 = A/2 + (A - B)^2 / 4 (B - 2R_1)$$

is satisfied. Before the tubes 1 are inserted into the holes 2a in the fins 2, an admixture of a mixture 6 and ethyl Cellosolve, as a kind of solvent, is applied to the outer surface 7 of each tube 1. This solvent is added in order that the mixture 6 of thermally conductive aluminum fine powder, each particle of which resembles a scale and

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has a thickness T of about $0.1 \mu\text{m}$ as shown in Fig. 4, and fixing agent is more firmly applied to tube 1. The fixing agent is produced by adding dicyanamide, as a hardening agent, to bisphenol epoxy, or an adhesive. Other Cellosolve solvents such as butyl Cellosolve and methyl Cellosolve, or ketone solvents such as acetone may be used as the solvent instead of ethyl Cellosolve. The adhesive may also be epoxy to which an aliphatic amine, an aromatic amine, a polyamide amine, or the like is added as a hardening agent. In this example, the aluminum fine powder, the fixing agent, and the solvent are mixed with a weight ratio of 27 : 18 : 55. For enhanced heat transfer, the proportion of the aluminum fine powder may be increased further. When top priority is placed on preventing the fine powder from scaling off, the ratio of the fixing agent may be made larger. When the admixture should be more firmly applied to the surface, the ratio of the solvent may be rendered greater.

The tubes 1 coated with the admixture in this way are inserted into the holes 2a in the fins 2, and these are provisionally assembled. Subsequently, the tubes are expanded until the outside dimension of each tube 1 becomes greater than the inside dimension of each unworked hole 2a in the fins 2, approximately 2 %, thereby joining the tubes to the fins. Thereafter, the assembly is subjected to a preliminary heating operation at a temperature of 100°C for

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10 minutes to cause the solvent to produce foam. Then, the assembly is heated at a temperature of 150°C for 30 minutes to cure the fixing agent. As shown in Fig. 5, the outer periphery 7 of each tube 1 and the inner surface 8 of each hole 2a of the fins 2 have a surface roughness of about 2 μmRz and are in contact with each other, resulting in minute gaps, where Rz is a unit for expressing the average roughness of ten measurements and is approximately $0.5 \mu\text{mRa}$ when expressed in terms of the average roughness along the center line. However, the mixture 6 enters the gaps to narrow the space, leading to a decrease in the thermal resistance at the contact surface between the tubes 1 and the fins 2. The result is that the heat exchange performance of the heat exchanger is improved. The solvent for enhancing the easiness of the application of the admixture has been volatilized by the preliminary heating at a temperature of 100°C for 10 minutes and by the heating at a temperature of 150°C for 30 minutes.

Since the gaps left in the holes 2a between the tubes 1 and the fins 2 are attributable to the surface roughness of the tubes 1 and the holes 2a, if the filling, thermally conductive fine powder is larger than the value of the surface roughness, then the powder may rather enlarge the gaps and increase the thermal resistance, thus deteriorating the heat exchange performance. Consequently,

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the size of the particles of the powder is required to be smaller than the value of the surface roughness at the boundary between the tubes 1 and the fins 2. However, in case where scalelike particles of aluminum fine powder are used as in the present example, as long as the thickness T is less than the value of the surface roughness of the tubes 1 and the fins 2, the width W is allowed to be greater than the surface roughness value, because the unevenness of the outer periphery 7 of each tube 1 and of the surface 8 of each fin 2 inside the holes 2a breaks or deforms the scalelike particles of the aluminum fine powder during the tube expanding operation, thereby filling up the gaps without almost enlarging the gaps. In the illustrative example, W is of the order of 10 μm .

If no adhesive is added to the scalelike particles of the powder, when the tubes 1 are cleaned or external vibration is given to the powder after the tube expanding operation, the particles filled in the gaps will gradually scale off. As a result, the heat exchange performance will also gradually be deteriorated. Hence, the scalelike particles of the fine powder are made fixed with adhesive to prevent them from scaling off from the gaps.

Although the particles of the thermally conductive fine powder take scalelike form in the above example, the form of the particles is not limited to this. For example,

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fine powder consisting of granular particles having a grain diameter less than the surface roughness value of the tubes 1 and of the fins 2 inside the holes 2a may also be used.

Further, the fixing agent added to the thermally
5 conductive fine powder is not limited to adhesive, but rather any other substance may be used as long as it exhibits water-proofness, shows no variation in its volume over a long period, and is capable of retaining the thermally conductive fine powder. Viscous substances such
10 as paints and greases are examples of them.

In addition, the material of the tubes, the fins, and the thermally conductive fine powder is not limited to aluminum and its alloy, but rather copper and its alloy may equally be used.

15 As described above, the solderless heat exchanger of the present invention has narrowed gaps between the tubes and the fins to facilitate the heat transfer, whereby improving the heat exchange efficiency. Additionally, the thermally conductive fine powder filled in the gaps between
20 the tubes and the fins is prevented from scaling off, and therefore the heat exchanger can retain its original performance over a long period.

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WHAT IS CLAIMED IS:

1. In a solderless heat exchanger having a plurality of fins, and tubes extending through holes formed in the fins, the tubes being joined to the fins by a tube expanding operation, the improvement comprising: a mixture
5 of a thermally conductive fine powder and a fixing agent provided in the interface between the fins and the tubes within the holes.
2. An improvement according to claim 1, wherein the mixture includes volatile solvent to ensure that the mixture is certainly applied to the interface.
3. An improvement according to claim 1, wherein the thermally conductive fine powder comprises scalelike particles of aluminum.
4. An improvement according to claim 1, wherein the fixing agent is an adhesive that is a bisphenol epoxy to which a dicyanamide is added as a hardening agent.
5. An improvement according to claim 1, wherein the thermally conductive fine powder comprises granular particles whose size is less than a value of the surface roughness at the interface between the fins and the tubes.
6. An improvement according to claim 2, wherein the volatile solvent is ethyl Cellosolve.
7. A method for joining a tube and a fin provided with a hole therein for a heat exchanger comprising

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the steps of:

forming a mixture of a thermally conductive fine
5 powder and a fixing agent,
applying the mixture to the tube,
inserting the tube into said hole of the fin, and
expanding the tube radially to join the fin to the
tube.

8. A method according to claim 7, wherein the
step of forming a mixture comprises the step of forming a
mixture further including a volatile solvent.

9. A method according to claim 7, wherein the
step of forming a mixture comprises the step of forming a
mixture wherein the thermally conductive fine powder
comprises scalelike particles of aluminum.

10. A method according to claim 7, wherein the
step of forming a mixture comprises the step of forming a
mixture wherein the fixing agent is an adhesive that is a
bisphenol epoxy to which a dicyanamide is added as a
5 hardening agent.

11. A method according to claim 7, wherein the
step of forming a mixture comprises the step of forming a
mixture wherein the thermally conductive fine powder
comprises granular particles whose size is less than a value
5 of the surface roughness at the interface between the fin
and the tube.

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12. A method according to claim 8, wherein the step of forming a mixture comprises the step of forming a mixture wherein the volatile solvent is ethyl Cellosolve.

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FIG. 1

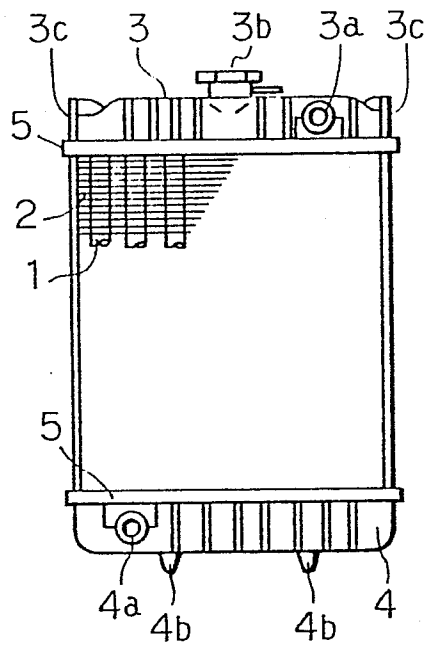


FIG. 2

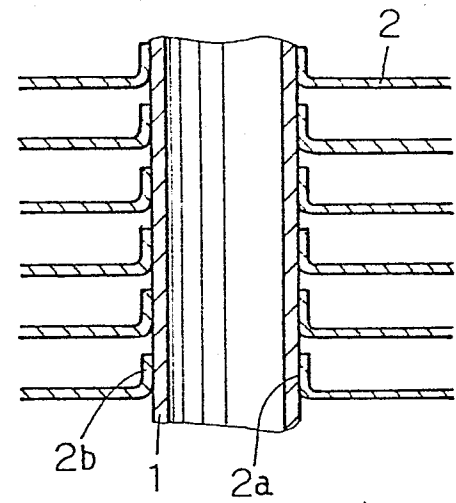
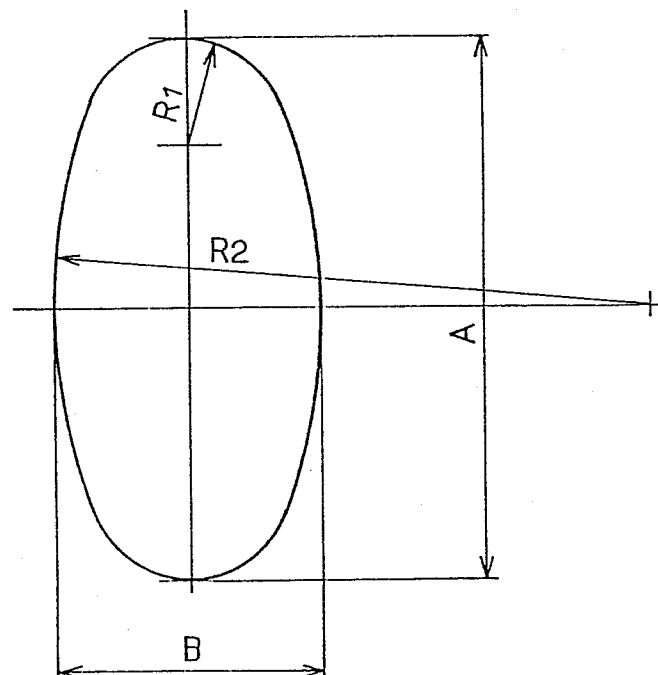


FIG. 3



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FIG. 4

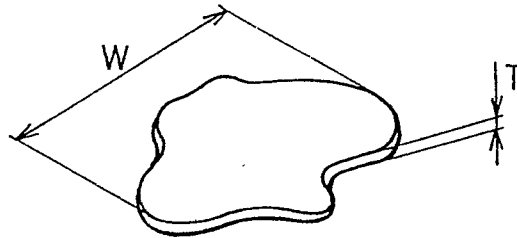
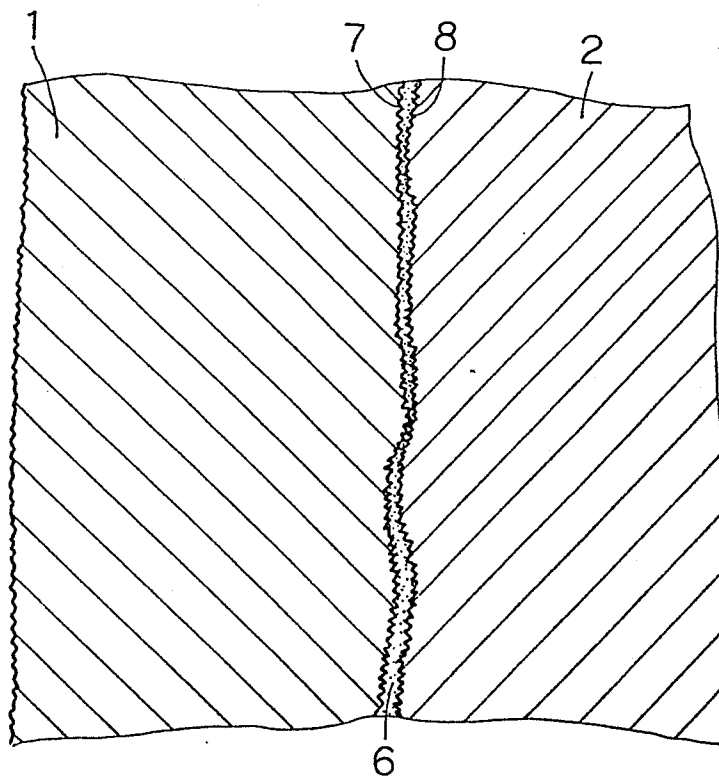


FIG. 5





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EUROPEAN SEARCH REPORT

0122612

Application number

EP 84 10 4163

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
X	GB-A- 558 124 (ABBEY) * Page 1, lines 49-61, 89-104; page 3, lines 5-28; figures 1,2 *	1-3,7- 10	F 28 F 13/00 F 28 F 1/12
Y		5,11	
A		4,12	
Y	--- GB-A-2 056 042 (NERATOOM) * Page 1, lines 63,75; figure 3 *	5,11	
Y	--- US-A-4 316 503 (NIPPONDENSO) * Column 3, lines 22-43 *	1,3,7, 9	
Y	--- US-A-3 683 478 (GLAY) * Column 3, lines 12-33 *	1,3,7, 9	TECHNICAL FIELDS SEARCHED (Int. Cl. 7) F 28 F F 28 D
A		4,10	
A	--- FR-A-2 499 234 (NIPPONDENSO) * Page 12, lines 3-29 * -----	7	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 17-07-1984	Examiner JEST Y.G.A.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			