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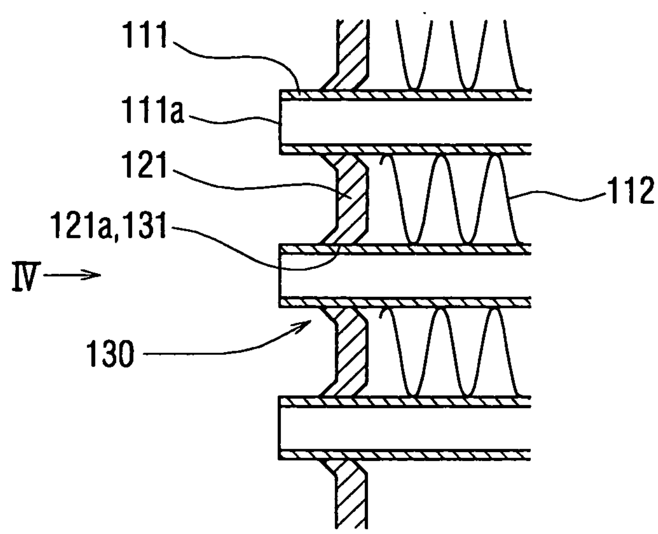
(54) **Tube insertion structure of a heat exchanger**

(57) A tube insertion structure of a heat exchanger includes a header tank (120) having a tube hole (121a), and a tube (111) having a rectangular cross-section inserted in the tube hole (121a) at a longitudinal end (111a) with an abutment portion (131) of the tube (111) brazed to the tank (120). A narrow side (111b) of the rectangular flat section of the tube (111) is expanded outwardly into a protruding arc shape in close proximity of the abutment portion (131) of the tube (111). The arc shape on the narrow side of the tube is formed simultaneously in a mouth of the tube (111) expansion process. In this manner, a durable rooted structure near the tube insertion portion of a heat exchanger with reduced suction friction of fluid flowing in the tube (111) is provided.

FIG. 3



EP 1 555 502 A2

Description

[0001] This invention relates to a tube insertion structure of a heat exchanger and its manufacturing method and, more specifically, to a structure of an intercooler that cools an intake air for combustion in an internal combustion engine.

[0002] A conventional heat exchanger such as an intercooler is disclosed in JP 2002-286395. This intercooler is for cooling an intake air for combustion in an internal combustion engine. The intercooler is formed of multiple tubes and outer fins alternately layered. Longitudinal ends of the tubes are connected to a header tank. A portion of the tube that connects to the tank, so called a 'rooted portion,' is formed by inserting the tube into a hole bored on a core plate of the header tank and brazing an abutment portion of the tube to the hole. (This is illustrated in FIG. 4 of JP 2002-286395.)

[0003] In this case, a cross-sectional area of the tube is maximized to decrease a suction friction of the intake air flowing in the tube. This helps increase a cooling capacity. The sectional area of the tube has a rectangular flat shape for maximized space utilization. (This is illustrated in FIG. 2 of JP 2002-286395.)

[0004] However, during operation of the intercooler, stress tends to accumulate near the corner of the rectangular shape in the tube around the abutment portion. This is due to variations in the temperature and pressure of the intake air. This stress reduces the life of the product.

[0005] In view of the above problems, it is an object of the present invention to provide a durable tube insertion structure of a heat exchanger with decreased suction friction of a fluid in the tube and a method of manufacturing the same.

[0006] The present invention uses the following technical elements to solve the problems. The invention is characterized by a tube insertion structure of a heat exchanger where a longitudinal end of a tube in a rectangular flat section is inserted in a tube hole on a header tank with an abutment portion of the tube brazed to the tank. The abutment portion is formed in an outwardly protruding shape on a narrow side of the rectangular flat section.

[0007] In this structure, an angle at a corner of the rectangular flat section at the abutment portion of the tube, that is, in the proximity of a rooted portion, can be increased. Therefore, heat stress and pressure stress in the proximity of the rooted portion of the tube caused by a heat exchanger operation are born uniformly by the arc-shaped narrow side. As a result, a lifetime of the rooted portion of the tube and its proximity is increased because those stresses less accumulate at the corner of the rectangular flat shape.

[0008] Friction between fluid in the tube and a wall of the tube will not be changed in this structure, because most of the entire passage except for the rooted portion of the tube is formed in a rectangular shape.

[0009] The present invention is further characterized by a radius of the arc shape formed on the narrow side of the rectangular flat shape being greater than one half of a distance between opposing broad sides.

[0010] In this manner, the rooted portion of the tube and its proximity are kept close to a basic shape, that is, a rectangular flat sectional shape. This contributes to increase a lifetime of the rooted portion.

[0011] Yet another aspect of the present invention is characterized by the tube and the header tank being used as components of an intercooler that cools an intake air for combustion in an internal combustion engine. The present invention is preferably used to improve a cooling capacity of the intercooler where a high temperature of the intake air increases heat stress in the heat exchanger.

[0012] A manufacturing method of a tube insertion structure of the heat exchanger is also another aspect that characterizes this invention. In this method, the longitudinal end of the tube in a rectangular flat section is inserted in the tube hole on a core plate formed as a part of the header tank. Then, a mouth on the longitudinal end of the tube is expanded outwardly towards the tube hole side by inserting an expansion jig so that the tube and the core plate can be brazed at the abutment portion to form a rooted portion of the heat exchanger.

[0013] In this manner, the narrow side of the rectangular flat section of the tube is formed in an arc shape and is expanded at the same time in a normal manufacturing process. Therefore, the rooted portion of the tube can be easily structured in a heat exchanger.

[0014] Other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings, in which:

FIG. 1 is a front view of an intercooler according to a first embodiment of the present invention;
FIG. 2 is a cross-sectional view of the intercooler taken along line II - II of FIG. 1;
FIG. 3 is a cross-sectional view of a portion of the intercooler encircled by line III of FIG. 1;
FIG. 4 is an end view of a tube of the intercooler as viewed from reference numeral IV in FIG. 3;
FIG. 5 is a perspective view of the tube of FIG. 4; and
FIG. 6 is a perspective view of an expansion jig approaching the intercooler of FIG. 1 during manufacture.

[0015] A rooted structure of a heat exchanger tube in the present invention is applied to an air-cooled intercooler 100. The embodiment is described with reference to FIGS. 1 to 6.

[0016] The intercooler 100 is used to exchanger heat between intake for combustion in an automotive engine (an internal combustion engine) and a cooling air to cool the intake air. The intercooler 100 includes a core 110 and a pair of header tanks 120. Each component described below is made of aluminum or an aluminum alloy. An abutment portion between those components is brazed to form a heat exchanger.

[0017] The core 110 includes, as shown in FIGS. 1 and 2, alternating layers of tubes 111 and outer fins 112 stacked between a pair of side plates 113. The tubes 11 include inner fins 114 disposed therein. The side plates 113 are disposed on opposite sides of the alternating layers of tubes 111 and outer fins 112.

[0018] For the sake of brevity only a single tube 111, outer fin 112, and side plate 113 will now be described in detail. The tube 111 is a pipe that lets the intake airflow pass therethrough. The tube 111 has a flat rectangular shape to reduce frictional losses of the intake air while maximizing its cross-sectional area in a limited space. The inner fin 114 disposed in the tube 111 is formed in a wave shape using a thin plate. The inner fin 114 causes turbulence in the intake air to increase heat conductivity of the intake air. The inner fin 114 is efficiently inserted in the tube 111 without leaving a dead space therein, because the section of the tube 111 is rectangular.

[0019] The outer fin 112 is similar to the inner fin 114 and is also formed in a wave shape using a thin plate. The outer fin 112 has multiple louvers 112a in a flat portion. The louvers 112a are formed by cutting and bending. These louvers 112a facilitate heat exchange of the intake air by expanding a heat dissipation area to the cooling air and by causing turbulence in the intake air.

[0020] The side plate 113 works as a reinforcement member that extends in a longitudinal direction of the tube 111. A section of the side plate 113 is formed approximately in a U shape. A rib is disposed at the center on the inside area of U shaped plate 113. The rib extends in the longitudinal direction of the tube 111.

[0021] The tube 111 is formed by folding plates with brazing filler on both sides and by electric-welding the folded plates at their edges. The outer fins 112 and the inner fins 114 are brazed on the tube 111 by the brazing filler. The side plate 113 has a side surface covered with brazing filler facing to the outer fin 112. The outermost outer fin 112 is brazed to the side plate 113 by the brazing filler.

[0022] The pair of header tanks 120 of the intercooler 100 are disposed on opposite sides of longitudinal ends 111a (tube end 111a hereinafter) of the tubes 111. The header tanks 120 connect the alternately stacked tubes 111 at the tube ends 111 a. The header tanks 120 are comprised of a core plate 121 that connects the tubes 111 and a tank body 122. The tank body 122 forms a tank space with the core plate 121 welded thereon.

[0023] The core plate 121, with a pre-coating of brazing filler on both surfaces, has a small side wall 121 b disposed on both broad sides, as shown in FIG. 6. The core plate 121 also has tube holes 121 a in areas corresponding to the tube ends 111a. The tube ends 111 a are inserted in the tube holes 121 a and brazed to the core plates 121 at an abutment portion 131 (shown in FIG. 3) by the pre-coated brazing filler on both of the tube 111 and the plate 121. The brazed area at the abutment portion 131 is formed as a so-called rooted portion 130. The longitudinal ends of the side plates 113 are brazed to the core plate 121 by the pre-coated brazing filler thereon.

[0024] The present invention is characterized by a shape of the tube 111 in the proximity of this rooted portion 130. More specifically, the rectangular tube 111 includes opposing narrow sides 111b and opposing broad sides 111c, as shown in FIGS. 4 and 5. The narrow sides 111b are expanded into protruding arcs in close proximity to the rooted portion 130. The narrow sides 111b therefore include an arc shape having a radius R1 that is greater than one half of a distance W between the two broad sides 111c of the tube 111.

[0025] In this embodiment, the tube 111 has a broad side measurement of 65 mm and a narrow side measurement of 8.9 mm. The arc shape of the narrow side 111b has a radius R1 of 8.6 mm. The broad side 111c and the arc shape of the narrow sides 111b are connected by an arc at a corner 111d having a radius of 2 mm.

[0026] The core plates 121 having tubes 111 connected thereto have, as shown in FIG. 1, the welded container-shape tank bodies 122 and define openings 122a. The header tank 120 on the right side in FIG. 1 distributes the intake air to the tubes 111. The header tank 120 on the left side in FIG. 1 collects the intake air flowing out from each of the tubes 111.

[0027] A method of manufacturing the intercooler 100 will now be explained. The tubes 111 formed from folded plates and electric welding, the outer fins 112 formed by pressing, the side plates 113, the inner fins 114, and the core plates 121 are prepared for manufacturing. The tubes 111 have generally flat rectangular cross sections at this point. The tube holes 121 a on the core plates 121 are bored in the shape corresponding to the section of the tube 111, as shown in FIGS. 4 and 5.

[0028] Then, the inner fins 114 are inserted into the tubes 111 and the tubes 111 are further flattened to securely press-fit the inner surface of the broad sides 111c against the inner fins 114.

[0029] Next, the core 110 is constructed by using a guiding layer jig (not shown). A predetermined number of outer fins 112 and tubes 111 are alternately layered between the two binding side plates 113.

[0030] The edges 111a of the tubes 111 are then press-fit into the tube holes 121 a bored through the core plates 121 with a press (not shown).

[0031] The mouth of the tubes 111 are expanded in the proximity of the tube holes 121 a (the rooted portion 130) with an expansion jig 200 (shown in FIG. 6). The expansion jig 200 is inserted in the tube ends 111a protruding from the core plates 121. The expansion jig 200 includes a main body 210 and expansion beaks 220 protruding from the main body 210. The outer surface of the expansion beaks 220 are in close proximity to the main body 210 and are formed in a shape corresponding to the final cross-sectional shape of the tube 111 (in an arc shape), as shown in FIGS. 4 and 5. Therefore, the expansion jig 200 expands the narrow sides 111b of the tubes 111 to form the arc shape in close proximity to the tube holes 121a (the rooted portion 130). Simultaneously, the expansion jig 200 securely press-fits the entire cross-sectional periphery of the tube 111 against the tube hole 121a (forming the abutment portion 131).

[0032] The core plates 121 are fitted to the core 110 by a jig including wire or the like to be brazed to each other in a brazing furnace after being treated for degreasing and flux coating.

[0033] The tank bodies 122 are formed by molding and are welded to the core plates 121. Subsequently, the tank bodies 122 are sent to a check process for leakage checks (checked for faulty brazing and faulty welding), dimension checks and the like to complete the manufacturing process of the intercooler 100.

[0034] The following is an explanation of the operation and effectiveness of the intercooler 100 constructed in the manner described above.

[0035] The intercooler 100 takes in intake air from the opening 122a on the right side in FIG. 1. Then, the intake air flows from the right header tank 120 into the tubes 111 toward the left header tank 120 to be fed to a vehicle engine through the opening 122a on the left side in FIG. 1. Heat from the intake air is dissipated to a cooling air by a heat exchange process while the intake air flows through the tubes 111. The temperature of the intake air is around 200°C at the time of intake into the intercooler 100 and the temperature is decreased down to 50°C by the heat exchange process.

[0036] During operation of the intercooler 100, stress is applied to the tubes 111 due to variations in the temperature and pressure (internal pressure) of the intake air. In a conventional intercooler, the stress tends to accumulate near the corners 111d of the tubes 111 in a rectangular shape around the rooted portion 130. This causes a reduced life of the product. In the present invention, the narrow sides 111b of the tubes 111 are formed in an arc shape in the proximity of the rooted portion 130. This helps widen the angle of the corners 111d. Therefore, the stress from the temperature/pressure variations in the proximity of the rooted portions 130 is born uniformly by the arc shaped narrow sides 111b during operation of the intercooler 100. Stress accumulation near the corners 111d is thus reduced. This helps increase durability of the rooted portions 130 of the tubes 111.

[0037] The radius R1 of the arc shaped narrow sides 111b is greater than one half of a distance W between the opposing broad sides 111c. According to this design, the proximity of the rooted portions 130 of the tubes 111 is kept close to the rectangular flat shape, which is the original shape of the tubes 111. This helps increase durability of this portion.

[0038] According to an analysis conducted by the inventor of the present invention, measurement of the stress near the corners 111d is reduced by 8% in a simulation of iterated variation of the intake air temperature between 20°C and 200°C. Furthermore, the stress at the corners 111d is reduced by 7% in a simulation of iterated variation of the intake air internal pressure between 0 bar and 3.5 bar.

[0039] Most portions of the tubes 111 other than the rooted portions 130 generally maintain the reduced suction friction of the intake air flowing in the tubes 111 because of the rectangular cross-sectional shape.

[0040] The arc shape of the narrow sides 111b of the tubes 111 and the normal mouth expansion process of the tubes 111 are conducted at the same time. Therefore, the rooted tube insertion structure of the intercooler 100 of the present invention is easily manufactured.

[0041] In the above-described embodiment, the present invention is applied to an intercooler 100. However, it should be appreciated that application of the invention is not limited to an intercooler. The invention can also be applied to other types of heat exchange devices such as condensers, radiators and the like.

[0042] Furthermore, it should be appreciated that the arc shape of the narrow sides 111b of the tubes 111 may be formed separately from the normal mouth expansion process. The tubes 111 may be arc-shaped as a single component after being formed as a tube by welding.

[0043] Although the present invention has been fully described in connection with the preferred embodiments and with reference to the accompanying drawings, it should further be appreciated that various changes and modifications will become apparent to those skilled in the art and that such variations and changes are intended to be within the scope of the present invention.

Claims

1. A tube insertion structure of a heat exchanger, comprising:

   a header tank (120) having a tube hole (121a); and
   a tube (111) having a generally rectangular cross-section disposed in the tube hole (121a) and having an abutment portion (131) defining a narrow side (111b) and opposing broad sides (111c), wherein
   the abutment portion (131) is fixed to the header tank (120) and the narrow side (111b) is arc-shaped in close proximity to the abutment portion (131) of the tube (111).

2. The tube insertion structure of claim 1, wherein
   the narrow side (111b) of the tube (111) includes a radius (R1) that is greater than one half of a distance (W) between the opposing broad sides

(111c) of the tube (111).

3. The tube insertion structure of either of claims 1 or 2, wherein
the tube (111) and the header tank (120) are components of an intercooler (100) that cools an intake air for combustion in an internal combustion engine.

4. The tube insertion structure of claim 1, wherein the abutment portion (131) of the tube (111) is brazed to the header tank (120).

5. A method for manufacturing a tube insertion structure of a heat exchanger comprising:

inserting a tube (111) having a generally rectangular cross-section into a tube hole (121a) of a core plate (121) formed as a part of a header tank (120);
expanding a mouth on a longitudinal end (111a) of the tube (111) outwardly against the tube hole (121a) such that a narrow side (111b) of the longitudinal end (111a) is formed to have an outwardly protruding arc shape near an abutment portion (131); and
fixing the abutment portion (131) of the tube (111) to the core plate (121).

6. The method of claim 5, wherein expanding the mouth includes inserting an expansion jig (200) into the tube (111) beyond the longitudinal end (111a).

7. The method of claim 5, wherein fixing the abutment portion (131) of the tube (111) to the core plate (121) includes brazing.

8. The method of claim 5, wherein the narrow side (111b) includes a radius (R1) that is greater than one half of a distance (W) between opposing broad sides (111c) of the tube (111).

FIG. 1

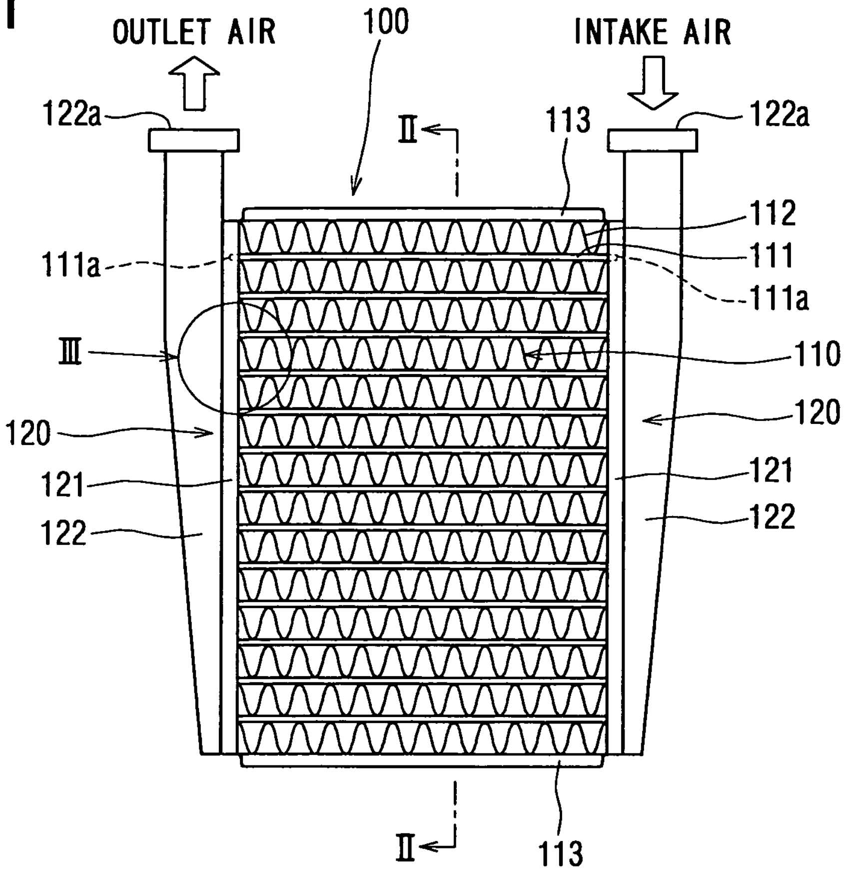

OUTLET AIR
100
INTAKE AIR
122a
122a
II
113
112
111a
111
111a
III
110
120
120
121
121
122
122
II
113

FIG. 2

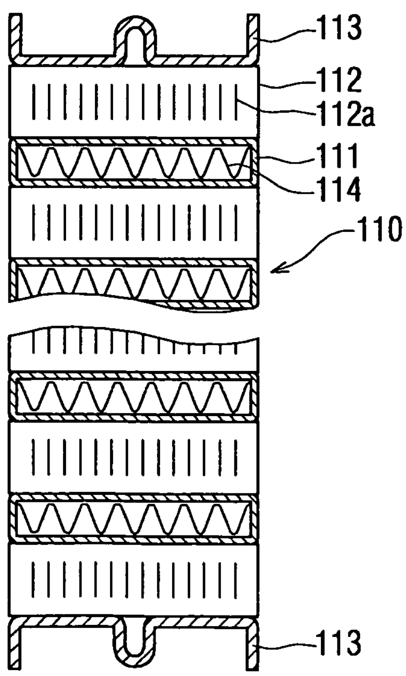

113
112
112a
111
114
110
113

FIG. 3

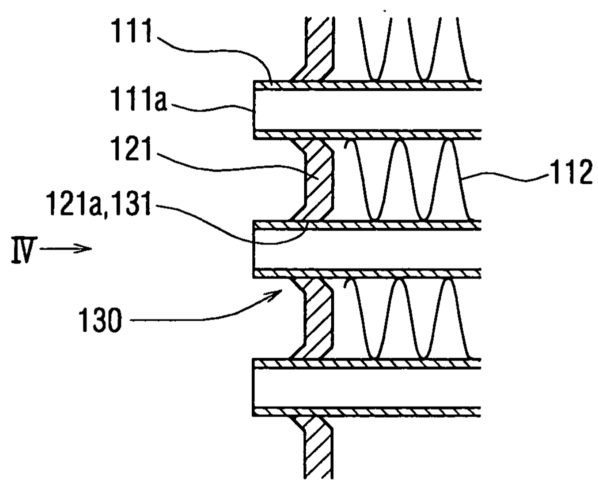


FIG. 4

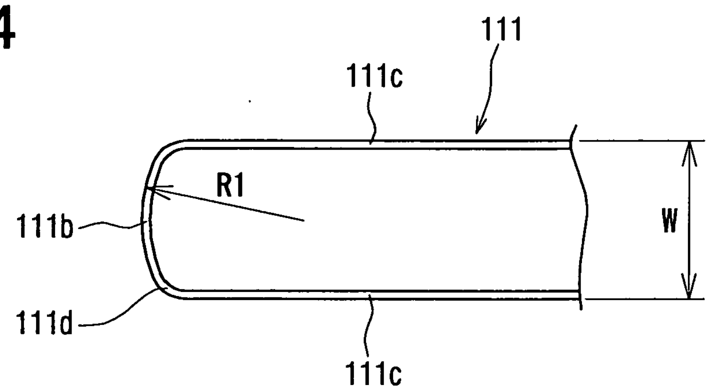


FIG. 5

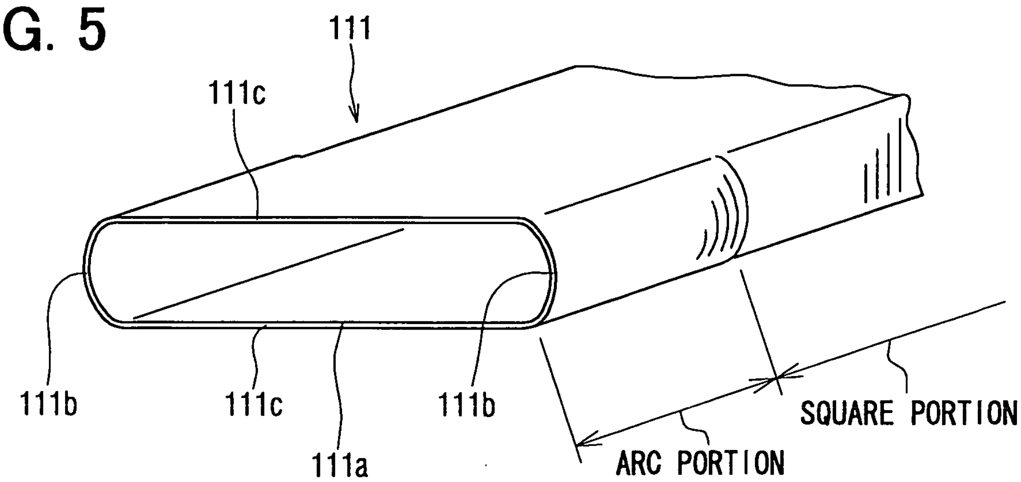


FIG. 6