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(54) **HEAT EXCHANGER TUBE, HEAT EXCHANGER COMPRISING SUCH TUBES AND METHOD FOR PRODUCING ONE SUCH TUBE**

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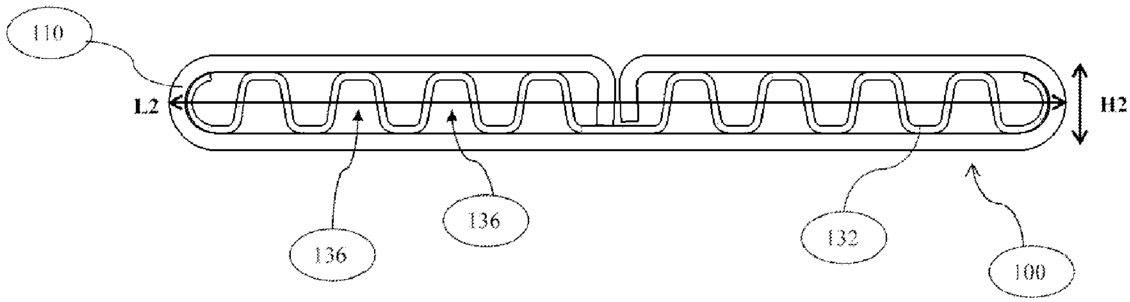
(57) **ABSTRACT**

Heat exchanger tube (**100**), in particular the condenser of a motor vehicle air conditioning system, is disclosed. The tube comprises a folded wall (**105**) defining a housing (**115**), and an internal separator (**130**), inserted into said housing, said internal separator defining a plurality of fluid circulation channels (**136**), said wall (**105**) having large surfaces connected by radii. The tube (**100**) is configured so that the clearance between the wall (**105**) and the internal separator (**130**) is filled along at least one radius (**110**).



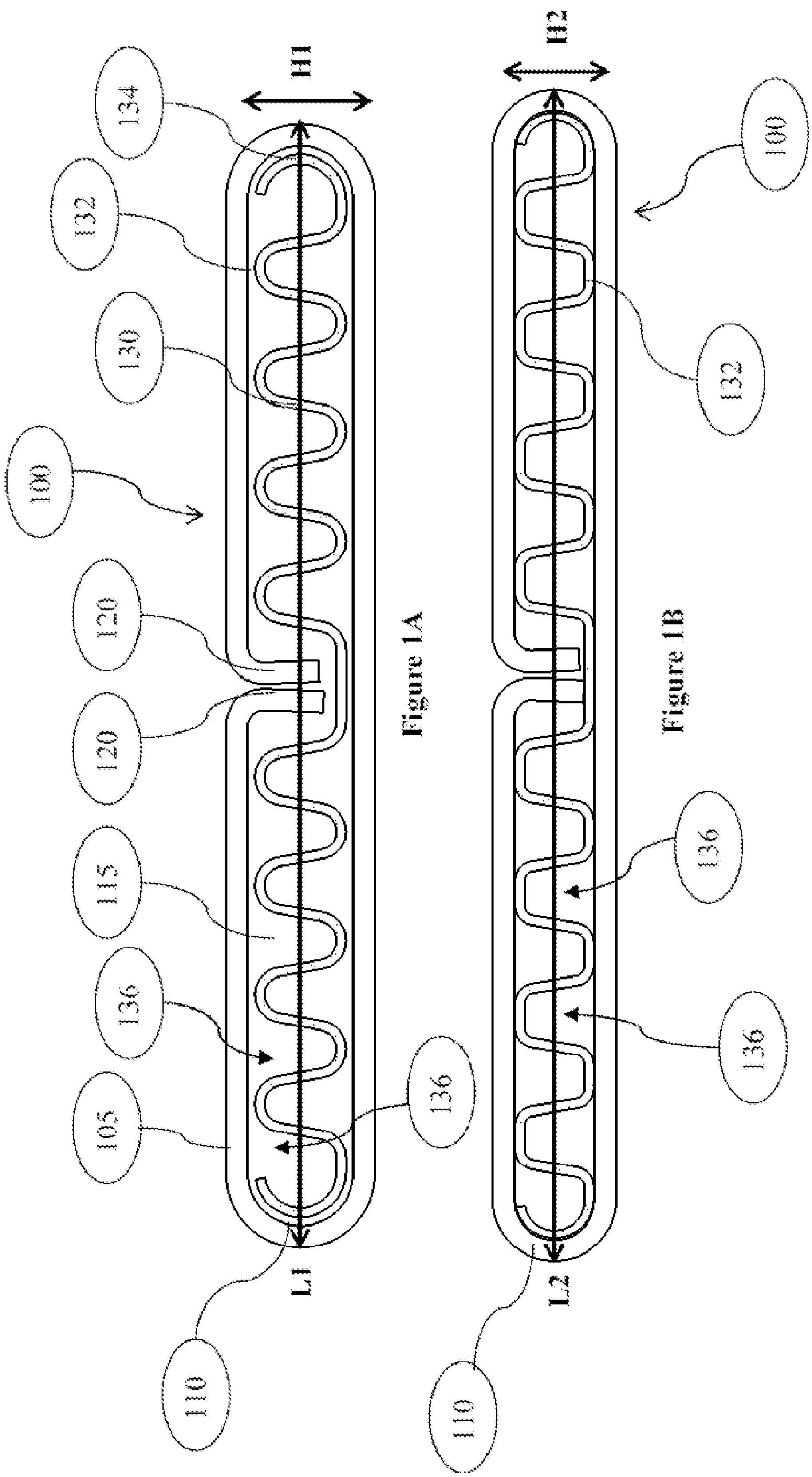


Figure 1A

Figure 1B

HEAT EXCHANGER TUBE, HEAT EXCHANGER COMPRISING SUCH TUBES AND METHOD FOR PRODUCING ONE SUCH TUBE

[0001] The present invention concerns a heat exchanger tube, a heat exchanger including such tubes and a method of producing such a tube.

[0002] Be it non-exclusively, the heat exchangers concerned are intended for equipping vehicles and, in a preferred application, correspond to the condensers provided in the air conditioning loops or circuits of the vehicles. There may nevertheless be envisaged, without departing from the scope of the invention, an application of these exchangers as radiators in engine cooling loops or circuits.

[0003] Briefly, the air conditioning loop of the passenger compartment of a vehicle generally consists primarily, in the direction of flow of the coolant fluid (for example freon, CO_2, 1234YF fluid) passing through it, a compressor compressing the fluid at this point in the form of vapor, a condenser receiving the fluid to convert it to liquid form thanks to a flow of external air sweeping it, an expander reducing the pressure and an evaporator, in which the expanded and condensed fluid exchanges heat with a flow of external air to be directed into the passenger compartment. The fluid is converted to the vapor phase at the outlet of the evaporator to be fed into the compressor for a new cycle, while the flow of external air passing through the evaporator is cooled to supply conditioned air in the passenger compartment.

[0004] In structural terms, the condenser forming the heat exchanger includes a bundle of parallel tubes and two manifolds (or collector boxes) into which the corresponding ends of the tubes are fixedly connected in sealed manner, by brazing them. Accordingly, the coolant fluid in the loop is able to flow through the tubes, the fluid being converted from its vapor phase to its liquid phase by the flow of external air sweeping the tubes.

[0005] Two technologies are primarily used to manufacture these tubes before assembly with the manifolds. Either extrusion, generating a high cost (dedicated dies for each type of tube) but easily brazable because naturally sealed, or bending, offering various advantages, but more difficult to braze.

[0006] The invention relates to heat exchanger tubes produced using the bending technology.

[0007] Such tubes are generally produced from a spool of sheet metal which, after it is paid out in strip form, is progressively shaped to the required cross section by dedicated bending tools or the like, and then cut to the required length, in sections corresponding to the finished tubes.

[0008] This being the case, the heat exchanger tubes may be subjected to numerous loads such as a high-speed impact with an object (for example a stone) from the exterior environment. The tube must be able to withstand any such impact so as to prevent any leaking of fluid. In the case of a bent tube, the tube cannot be reinforced by an increased thickness of material as is the case for an extruded tube. It is however necessary to increase the thickness of the wall of the bent tube locally as the latter thickness is generally around 0.2 mm, which is insufficient from the point of view of withstanding stone impacts.

[0009] In a first known bent tube, the wall of the tube is bent horizontally on itself several times at the level of one side or nose of the tube, increasing the thickness of material in the tube nose. A drawback is that the height of the tube is thus a function of the thickness of material thereof and corresponds to the number of bends.

[0010] In another known bent tube, the tube is open beforehand along one of its sides that is then closed by overlapping plane on plane two thicknesses of wall. A drawback of a solution of this kind is the risk of defective sealing at the level of the side closed in this way.

[0011] The patent DE102006006670 describes a solution including sides having numerous vertical bends. A major drawback of this solution is that it leads to excess consumption of material.

[0012] The patent U.S. Pat. No. 6,192,977 describes a tube one end of which is constituted by the overlapping of the wall of the tube. This solution is difficult to control in the case of tubes of low height, for example of the order of 1 mm.

[0013] Furthermore, there are also known, notably from the patent DE102005043093, tubes with an internal separator. With a tube and an internal separator, it is not possible to proceed to cut the tube and the internal separator to length with conventional means (for example cutting with a knife), because the internal separator tends to be compressed during this operation. In this case, the tube is first shaped and then cut to length, the internal separator is also shaped and then cut to length, and the tube and the internal separator are then assembled. In this configuration it is necessary to leave a functional clearance between the tube and the internal separator to be able to insert the latter. This clearance is not favorable for correct brazing of the components to each other.

[0014] In the existing solutions, the contacts between the internal separator and the walls of the tube necessary for increasing the mechanical strength are not necessarily guaranteed. Moreover, in the existing solutions, the problem of stone impact remains.

[0015] An object of the present invention is to remedy these drawbacks and the present invention concerns a fluid circulation tube the design of which enables the internal separator to reinforce the tube and notably at least one side of the tube.

[0016] To this end, the heat exchanger tube comprises a bent wall defining a housing and an internal, for example corrugated, separator inserted into the housing. The internal separator defines a plurality of fluid circulation channels. The wall of the tube has large surfaces connected by radii. The internal separator extends in the lengthwise direction, for example, from one orifice to the other of the tube. The large surfaces are notably plane and parallel to each other.

[0017] According to the invention, the tube is configured so that the clearance between the wall and the internal separator is filled along the length of at least one radius. In other words, considering the tube in cross section, i.e. in a section plane orthogonal to its longitudinal axis, the clearance between the internal separator and the wall of the tube is filled along the radius, over all or part of the length of the internal separator. The effect of this is to increase the overall area of contact between the separator and the walls of the tube, and therefore the thickness of the tube, at least at the level of the nose of the tube.

[0018] According to one aspect of the present invention, the internal separator includes at least one flat at one apex, said flat being in contact with the wall. This has the advantage of increasing the mechanical strength, including at the level of its plane faces.

[0019] According to one aspect of the present invention, the internal separator includes a flat at each of its vertices, said flat being in contact with the wall.

[0020] According to one aspect of the present invention, the tube is configured so that the clearance between the wall and the internal separator is filled along each radius. This has the advantage of reinforcing the tube noses on each side of the tube and thus avoiding the necessity to mark the reinforced side.

[0021] According to one aspect of the present invention, the tube has a section in the shape of a B and said wall comprises legs that meet at the level of a central portion of said B-shaped section. At least one of said legs is in contact with the internal separator. This has the advantage of increasing the mechanical strength of the tube.

[0022] It is to be noted that, according to the invention, these various features are encountered both in a tube once brazed and in a tube not yet brazed.

[0023] The invention also concerns a heat exchanger that includes tubes as defined above. The heat exchanger with these fluid circulation tubes preferably defines the condenser of a motor vehicle air conditioning loop or the like. As indicated above, such a heat exchanger finds a particular application in the field of motor vehicles, for example to produce an air conditioning condenser.

[0024] The exchanger has the structure referred to above, for example.

[0025] The invention also concerns a method of producing a heat exchanger tube, in particular the condenser of a motor vehicle air conditioning system. The tube comprises a bent wall defining a housing and an internal separator, which is for example corrugated, inserted into the housing with a clearance. The internal separator defines a plurality of fluid circulation channels and the wall of the tube has large surfaces, notably plane surfaces, of length L connected by radii of height H. The method comprises the steps of inserting the internal separator in the housing and compressing the tube in the direction of its height. According to the invention the compression is characterized in that it compresses the tube from a height H**1** to a height H**2** with $H2<H1$ and from a length L**1** to a length L**2** with $L1<L2$, so that the clearance between the wall and the internal separator is at least partially filled.

[0026] By compressing the tube from a height H**1** to a height H**2** with $H2<H1$ and from a length L**1** to a length L**2** with $L1<L2$, the compression enables the overall area of contact between the insert and the walls of the tube to be increased, notably at the level of at least one tube nose. This has the advantage of enabling better brazing between the internal separator and the walls of the tube in contact with the internal separator. Another advantage of the method of the invention is that the compression (i.e. deformation) enables linear and homogeneous reshaping of the tube including the internal separator.

[0027] According to one aspect of the present invention, the method includes a preliminary step wherein the wall of the tube is produced by bending a sheet of material, for example, and has, after bending, a substantially closed section in which the internal separator is inserted.

[0028] According to one aspect of the present invention, during the compression step of the method, the compression is exerted in a direction substantially orthogonal to the plane faces of the tube.

[0029] According to one aspect of the present invention, the compression step is configured so that the tube and its components, wall and/or insert, have the features referred to above.

[0030] The appended figures explain how the invention may be reduced to practice. In these figures, identical references design similar elements.

[0031] FIG. **1**A represents a tube bent into the shape of a B before compression in accordance with one embodiment of the invention and including an internal separator inserted between the walls of the tube.

[0032] FIG. **1**B represents the tube from FIG. **1**A after compression.

[0033] As shown in FIG. **1**A and **1**B and in accordance with the invention, a heat exchanger tube **100**, notably of an air conditioning condenser for motor vehicles, comprises a bent wall **105**, defining a housing **115**, and an internal separator **130**, inserted in the housing. The internal separator **130**, which is notably corrugated, defines a plurality of fluid circulation channels **136**. The wall **105** has large, for example plane, surfaces connected by radii **110**. The wall of the tube notably has a cross section in the shape of a B.

[0034] In other words, in the example shown, once the tubes have been bent and then cut into sections, their thin wall has a cross section in the overall shape of a flattened B, i.e. with a base part extended laterally, by way of two connecting parts, by two coplanar, facing top parts parallel to the base part that terminate in adjacent end legs, facing perpendicularly toward the base part, and separated from the latter. Two longitudinal and parallel internal spaces or channels, corresponding to the loops of the B, are then defined in which are inserted, to their full length and in known manner, the two arrays of bends of an internal separator or disturber that are interconnected by a plane connecting part inserted in the space left between the end legs and the base part of the bent wall of the tube.

[0035] This inner spacer or each of these inner spacers notably also has the function of improving the thermal performance of the condenser and the mechanical strength of the tubes, which must resist not only the operating pressure when the loop is operating, which is of the order of 20 bar, but also that imposed by the specification, notably a tube bursting rating of up to 100 bar, for coolant fluids based on freon. Clearly, after the pre-assembled condenser (tubes, with internal separators, nested in the manifolds) is placed in a brazing furnace notably enabling fastening of the vertices of the longitudinal and corrugated bends of each internal separator to the internal face of the wall bent into the shape of a B of each tube, thanks to cladding provided on them (on the internal separator and/or on the wall of the tube) and the melting point of which is slightly lower than that of the material constituting the wall of the tubes and internal separators (for example aluminum alloy).

[0036] According to the invention, the tube **100** is configured so that the clearance is filled along at least one radius **110** between the wall **105** and the internal separator **130**. The clearance is defined by the space that exists between the internal radius of the radius **110** of the tube **100** and the curvature of the end **134** of the internal separator **130**. This means that the contact is continuous so that the clearance between the wall **105** and the internal separator **130** is entirely filled over all the length of the radius (i.e. along all the curvature of the radius). The tube is configured so that the clearance between the wall **105** and the internal separator **130** is for example filled along each radius **110**.

[0037] In the embodiment shown, the internal separator **130** includes at least one flat at a vertex **132**, notably at each vertex **132**, said flat being in contact with the wall.

[0038] As already stated, the tube **100** has, for example, a section in the shape of a B and the wall has legs **120** joined at the level of the central part of said B-shaped section, at least one of the legs **120** being in contact with the internal separator **130**.

[0039] The invention further concerns a method of producing a heat exchanger tube, notably for motor vehicle air conditioning system condensers. According to the invention, the tube **100** comprises a wall **105** defining a housing **115** and an internal separator **130** inserted in the housing **115**. The internal separator **130** defines a plurality of fluid circulation channels **136**. The wall has large, notably plane, faces of length L connected by radii of height H. As shown in FIGS. **1**A and **1**B, the length L corresponds to the dimension of the tube **100** in the direction of its longitudinal section. As shown in FIGS. **1**A and **1**B, the height H corresponds to the overall thickness of the tube **100**, i.e. its thickness in the direction of its cross section. Of course, although this is not represented, the tube extends along its longitudinal axis, orthogonal to the plane of FIGS. **1**A and **1**B.

[0040] The method of the invention includes a first step in which the internal separator **130** is inserted into the housing **115** of the tube **100** with a clearance.

[0041] The method of the invention includes a second step in which the tube **100** is compressed in the direction of the height H. This compression is characterized in that it enables the tube to be compressed from a height H**1** to a height H**2** with H2<H1 and from a length L**1** to a length L**2** with L1<L2, the tube **100** being configured after compression so that the clearance between the wall **105** and the internal separator **130** is at least partially filled.

[0042] The compression step may be generalized to a deformation step without limiting the scope of the protection of the present invention.

[0043] The compression or deformation step enables the wall **105** and the internal separator **130** to be calibrated. This step enables reshaping of the tube **100**, the dimensions of which are modified. Before reshaping, there exists a clearance in the direction of the height H and also in the direction of the length L that enables the insertion of the internal separator **130**. The dimensions of the wall **105** and the internal separator **130** can be defined beforehand so that this clearance exists despite the manufacturing tolerances of the two parts. A reshaping dimension is then defined in order to calibrate the tube **100** and the internal separator **130** and to fill at least one clearance or even all of the clearances provided for the purpose of this insertion.

[0044] The compression step enables the height H to be reduced and the length L to be increased. The effect of this is to fill the clearance along the radius between the wall **105** and the internal separator **130** and to enable brazing of the components. By virtue of their design, the increase in the dimension L of the wall **105** will be less than that of the internal separator **130**.

[0045] In other words, the compression step makes it possible to increase the length dimension L of the internal separator **130** more than that of the wall **105**. This makes it possible to fill the assembly clearance between the internal separator **130** and the inside radius of the tube nose **110**. This moreover makes possible the brazing of the two components (i.e. wall **105** and internal separator **130**) and thus to increase the mechanical strength, notably at the level of the tube nose **110**.

[0046] The method could include a preliminary step in which the wall of the tube is produced by bending a sheet of material, for example, and after bending has a substantially closed section into which the internal separator is inserted.

[0047] In one embodiment, during the compression step of the method, the compression is exerted in a direction substantially orthogonal to the plane faces of the tube.

[0048] The compression step is configured so that the tube and its components, wall and/or internal separator, have the features referred to above, for example.

[0049] To be more precise, the compression step could be configured so that, after compression, the internal separator **130** includes a flat at one at least of its vertices **136**, said flat being in contact with the wall.

[0050] The compression step thus enables the production of the plane areas at some or all of the vertices **136** of the internal separator **130**. In other words, the consequences of the reduction in the height are crushing of the internal separator **130** generating a flat at its vertex and, depending on the magnitude of the calibration, modifying the angles of the bends of the internal separator **130**. The effect of this is to guarantee the brazing between the internal wall of the wall **105** and the internal separator insert **130** as well as to increase the mechanical strength of this combination.

[0051] The compression step could also be configured so that the clearance between the wall **105** and the internal separator **130** is filled along each radius **110**.

[0052] The compression step could further be configured so that, after compression, at least one of said legs **120** is in contact with the internal separator **130**.

1. A heat exchanger tube comprising a bent wall defining a housing and an internal separator inserted into said housing, said internal separator defining a plurality of fluid circulation channels and said wall having large surfaces connected by radii, wherein the tube is configured so that the clearance between the wall and the internal separator is filled along the length of at least one radius.

2. The tube as claimed in claim **1**, wherein the internal separator is corrugated and includes at least one flat at one apex, said flat being in contact with the wall.

3. The tube as claimed in claim **1**, wherein the internal separator is corrugated and has a flat at each of its vertices, said flat being in contact with the wall.

4. The tube as claimed in claim **1**, wherein said tube is configured so that the clearance between the wall and the internal separator is filled along each radius.

5. The tube as claimed in claim **1**, wherein said tube has a section in the shape of a B and said wall includes legs that meet at a central portion of said B-shaped section, at least one of said legs being in contact with the internal separator.

6. A heat exchanger including at least one tube as claimed in claim **1**.

7. A method of producing a heat exchanger tube, said tube comprising a bent wall defining a housing and an internal separator inserted into said housing, said internal separator defining a plurality of fluid circulation channels and said wall having large surfaces of length L connected by radii of height H, said method comprising the steps of:

inserting an internal separator in the housing of the tube with a clearance; and compressing the tube in the direction of its height, said compression compressing the tube from a height H**1** to a height H**2** with H2<H1 and from a length L**1** to a length L**2** with L1<L2, the tube being configured after compression so that the clearance between the wall and the internal separator is at least partially filled.

8. The method as claimed in claim **7**, including a preliminary step wherein the wall of the tube is produced by bending a sheet of material, said wall having, after bending, a substantially closed section in which the internal separator is inserted.

9. The method as claimed in claim **7**, wherein the compression is exerted in a direction substantially orthogonal to the plane faces of the tube.

10. A method of producing a heat exchanger tube, said tube comprising a bent wall defining a housing and an internal separator inserted into said housing, said internal separator defining a plurality of fluid circulation channels and said wall having large surfaces of length L connected by radii of height H, said method comprising the steps of:

inserting an internal separator in the housing of the tube with a clearance; and

compressing the tube in the direction of its height, said compression compressing the tube from a height H**1** to a height H**2** with H2<H1 and from a length L**1** to a length L**2** with L1<L2, the tube being configured after compression so that the clearance between the wall and the internal separator is at least partially filled, wherein the compression step is such that the tube and its components, wall or internal separator, have the features as claimed in claim **1**.

11. The tube as claimed in claim **1**, wherein the tube is part of a condenser of a motor vehicle air conditioning system.

12. The heat exchanger as claimed in claim **6**, wherein the heat exchanger is a condenser of a motor vehicle air conditioning system.

13. The tube as claimed in claim **2**, wherein said tube is configured so that the clearance between the wall and the internal separator is filled along each radius.

14. The tube as claimed in claim **3**, wherein said tube is configured so that the clearance between the wall and the internal separator is filled along each radius.

15. The method as claimed in claim **8**, wherein the compression is exerted in a direction substantially orthogonal to the plane faces of the tube.

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