HEAT EXCHANGER FOR GAS, PARTICULARLY FOR ENGINE EXHAUST GASES

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ABSTRACT

A heat exchanger uses engine exhaust gases. The heat exchanger comprises a plurality of parallel tubes arranged inside a header and through which the gases to be cooled by exchange of heat with a coolant flow, and fins that disturb the flow of the gas and that are arranged inside each tube. The tubes and the header comprise a plurality of protrusions and respectively, the distribution pattern and dimensions of which are defined according to the dimensions of the tubes and of the header and which are able to guarantee suitable distribution of the compression between the header, the tubes and the fins relative to one another while the heat exchanger is being assembled and brazed in the furnace.
Sensitivity of the position of the protuberances

Fig. 17

Sensitivity of the thickness of the welding material

Fig. 18
HEAT EXCHANGER FOR GAS, PARTICULARLY FOR ENGINE EXHAUST GASES

[0001] The present invention relates to a heat exchanger for gas, in particular for the exhaust gases of an engine.
[0002] The invention is used more specifically in heat exchangers for recirculating exhaust gases of an engine (EGRC).

BACKGROUND OF THE INVENTION

[0003] In some heat exchangers for cooling gas, for example those used in systems for recirculating exhaust gases towards the input of a positive-ignition engine, the two media which exchange heat are separated by a wall.
[0004] The basic principle in a heat exchanger is the exchange of heat between two fluids at different temperatures. The hot fluid and the cold fluid conventionally flow through independent circuits which are located as close as possible to each other. The efficiency of the exchange depends on the mass flow rate, the speed, the specific heat and the temperature of each fluid relative to the other. The design of each circuit, the design of the partition wall and the raw materials are also important.
[0005] The current configuration of EGR exchangers present on the market corresponds to a metal heat exchanger which is generally made of stainless steel or aluminum.
[0006] The heat exchanger itself may have different configurations: for example, it may consist of a casing inside which there are arranged a series of parallel conduits for the passage of gases, the cooling fluid flowing in the casing, outside the conduits; in another embodiment, the exchanger is composed of a series of parallel plates which form the heat exchange surfaces so that the exhaust gases and the cooling fluid flow between two plates, in alternate layers.
[0007] In the case of heat exchangers having a bundle of conduits, the assembly between the conduits and the casing may be of different types. Generally, the conduits are fixed by means of the ends thereof between two support plates which are connected at each of the casing, the two support plates having a plurality of holes for positioning the respective conduits. These support plates are in turn fixed to means for connection to the recirculation conduit.
[0008] These connection means may consist of a V-shaped branch or a peripheral connection edge or flange, depending on the design of the recirculation conduit where the heat exchanger is assembled. In some cases, the support plate is constructed in one piece with the connection means and forms a single connection flange. The connection means may also consist of a gas reservoir which is arranged at one or both ends of the casing.
[0009] In the two types of EGR exchanger, the majority of the components thereof are metal so that they are assembled using mechanical means and then welded in a furnace, or arc or laser-welded, in order to ensure the appropriate sealing required by this application. In some cases, they may also comprise some components made of plastics material, which may have a single function or several functions integrated in a single component.
[0010] In tubular exchangers, it is known to use fins or undulations inside the heat exchange circuits since they contribute to improving the heat exchange and the mechanical strength of the heat exchanger.

[0011] The undulations or fins help to guide the fluid so that it can correctly fill the entire circuit, promote heat exchange and improve the mechanical strength when there is an increase of pressure in the circuit.
[0012] Patent application ES 2331218, from the same patentee as the present application, describes a tubular heat exchanger having a casing which comprises a series of protuberances which are stamped on its surface and directed towards the inside thereof so that the protuberances are arranged at a predetermined distance relative to the assembly of tubes, which thus ensures controlled expansion of the tubes in the event of a pressure increase.
[0013] Patent JP20010130114 describes a heat exchanger which comprises a bundle of gas tubes having a rectangular cross-section, inside which tubes it comprises fins having a notched cross-section and whose smooth portions (which form the peak and the trough) are in contact with the inner surface of the tube, and a plurality of protuberances arranged in the walls of the tube opposite the smooth portions of the fins. This arrangement of the protuberances allows the correct positioning of the fin inside the tube and prevents it from becoming disengaged.
[0014] Patent DE 19961054368 describes a heat exchanger which comprises a bundle of gas tubes having a rectangular cross-section arranged inside a casing. The tubes comprise protuberances which are directed towards the outside and which determine the distance between adjacent tubes and relative to the inner surface of the casing.
[0015] It is known that, during assembly, successful integration of the fins inside the tubes is achieved only if the fins may be completely soldered to the tubes. If this is not the case, the mechanical strength and the increase of the thermal yields cannot be ensured.
[0016] Furnace soldering of the assembly formed by the tubes, the casing and the fins is carried out after complete assembly of the various components of the exchanger. However, the quality of the final furnace welding will be appropriate only on the condition that complete contact of the components is ensured during furnace soldering.

DESCRIPTION OF THE INVENTION

[0017] The objective of the heat exchanger for gas, in particular the exhaust gases of an engine, according to the present invention is to overcome the disadvantages of the exchangers known in the art by providing excellent distribution of the compression between the assembled components and good furnace soldering of the exchanger.
[0018] The heat exchanger for gas, in particular for the exhaust gases of an engine, to which the present invention relates is of the type which comprises a plurality of parallel tubes which are arranged inside a casing and via which the gases to be cooled by means of heat exchange with a cooling fluid circulate, and fins which disrupt the flow of gas and which are arranged inside each tube, and is characterised in that the tubes and the casing comprise each a plurality of protuberances whose distribution pattern and dimensions are defined in accordance with the dimensions of the tubes and the casing, and which are capable of ensuring good distribution of the compression between the casing, the tubes and the fins with respect to one another during the furnace welding of the exchanger.
[0019] The invention is consequently based on a pattern and specific dimensions of the protuberances which are arranged on the surface of the casing and the tubes.
In this manner, optimum configuration of the tubes is achieved in order to obtain good furnace soldering of the fins used. At the same time, the configuration improves the durability of the mechanical strength for the service-life of the exchanger.

The advantages achieved owing to the configuration of the protuberances according to the invention are described below:

The casing of the exchanger allows the tubes and the fins to be compressed at the same time.

The tubes, after assembly, allow the fins to be compressed in order to ensure good contact with the tubes.

The contact of the casing and the tubes is ensured by the contact of the protuberances. These protuberances at the same time allow distribution of the cooling fluid and contact between the components.

The casing and the tubes have the same protuberance pattern so that the components are compressed at the same time.

The pattern and the dimensions of the protuberances allow excellent distribution of the compression to be obtained, and ultimately good furnace welding of the exchanger.

Preferably, the protuberances are produced by means of stamping, each protuberance comprising a protruding contact surface which is substantially planar and circular and a frustoconical side defined by a stamping angle and connection radii relative to said contact surface and to the surface of the tube or the casing where the protuberance is stamped.

Advantageously, the dimensions of the protuberances of both the tubes and the casing are defined by their diameter and height, the stamping angle and the connection radii at the frustoconical side.

Also in an advantageous manner, the distribution pattern of the protuberances on the tubes is defined in accordance with the thickness, the width and the length of the tube itself, the tubes having a substantially rectangular cross-section and being provided with two opposing flat sides which are wider than they are high.

Preferably, the protuberances are arranged on the two opposing flat sides of the tubes, orientated towards the outside of the tube and distributed in one or more longitudinal rows in accordance with the width of the tube.

In accordance with a first embodiment for the tubes, the protuberances of the same row on the tubes are spaced apart by a predetermined distance defined by the length of the tube, and the first protuberance of the corresponding row is arranged relative to an of the tube at a predetermined distance which is also defined by the length of the tube.

In accordance with a second embodiment for the tubes, the protuberances on the tubes are distributed over two mutually parallel, longitudinal rows which are equidistant relative to a longitudinal axis of symmetry and which are spaced apart by a predetermined distance which is defined in accordance with the width of the tube.

Preferably, between the two rows of protuberances on the tubes there are two reinforcement protuberances which are each located relative to an of the tube at a predetermined distance defined by the length of the tube.

Advantageously, the distribution pattern of the protuberances on the casing is defined in accordance with the width of the tube and the thickness, the width and the length of the casing, the casing having a substantially rectangular cross-section.

Preferably, the protuberances are arranged on at least one side of the casing, directed towards the inside of the casing and distributed in one or more groups of two longitudinal rows in accordance with the width of the casing.

In accordance with a first embodiment for the casing, the protuberances of the same row on the casing are spaced apart by a predetermined distance which is defined by the length of the casing, and the first protuberance of the corresponding row is arranged relative to one of the casing at a predetermined distance which is also defined by the length of the casing.

In accordance with a second embodiment for the casing, the protuberances on the casing are distributed in two groups of two mutually parallel, longitudinal rows which are spaced apart by a predetermined distance defined in accordance with the width of the casing, and the two groups of two rows are equidistant relative to a longitudinal axis of symmetry.

Preferably, between the two rows of protuberances of each group there are two reinforcement protuberances which are each located relative to an of the casing at a predetermined distance which is defined by the length of the casing.

Advantageously, the protuberances may have different shapes such as, inter alia, circular, cross-like, diamond-like or linear.

**BRIEF DESCRIPTION OF THE DRAWINGS**

In order to facilitate the description of what is set out above, drawings are appended in which there are illustrated schematically and only by way of non-limiting example various practical cases of an embodiment of the heat exchanger for gas, in particular for the exhaust gases of an engine, according to the invention, in which:

**FIG. 1** is a perspective view of a known heat exchanger provided with protuberances on the casing;

**FIG. 2** is a perspective view of the heat exchanger of **FIG. 1**, without the gas reservoirs and along a longitudinal section of the casing in order to show the assembly of parallel tubes accommodated therein;

**FIG. 3** is a view along a cross-section of a tube showing the fins which are accommodated inside it and the protuberances according to the invention;

**FIG. 4** is a perspective view of a tube with a single row of protuberances according to a first embodiment of the invention;

**FIG. 5** is a front view of the tube of **FIG. 4**;

**FIG. 6** is a partial cross-section of **FIG. 5**;

**FIG. 7** is a detailed cross-section of a protuberance of the tube along the line VII-VII of **FIG. 6**;

**FIG. 8** is a plan view of the casing with a group of two rows of protuberances, according to the first embodiment of the invention;

**FIG. 9** is a detailed cross-section of a protuberance of the casing along the line IX-IX of **FIG. 8**;

**FIG. 10** is a perspective view of a tube with two rows of protuberances according to a second embodiment of the invention;

**FIG. 11** is a front view of the tube of **FIG. 10**;

**FIG. 12** is a plan view of the tube of **FIG. 10**;

**FIG. 13** is a detailed cross-section of a protuberance of the tube along the line XIII-XIII of **FIG. 12**;
FIG. 14 is a plan view of the casing with two groups of two rows of protuberances, according to the second embodiment of the invention;

FIG. 15 is a detailed cross-section of a protuberance of the casing along the line XV-XV of FIG. 14;

FIGS. 16a to 16c are plan views of five protuberances which have different shapes and orientations;

FIG. 17 is a diagram relating to the sensitivity of the position of the protuberances; and

FIG. 18 is a diagram relating to the sensitivity of the thickness of the soldering material.

DESCRIPTION OF PREFERRED EMBODIMENTS

With reference to FIGS. 1 to 3, the heat exchanger 1 for gas, in particular for the exhaust gases of an engine, comprises an assembly of parallel tubes 2 which, in this example, are flat, have a rectangular cross-section and are intended for the circulation of the gases with an exchange of heat with a cooling fluid. Said assembly of parallel conduits 2 is accommodated inside a casing 3 which, in this instance, also has a rectangular cross-section.

FIG. 2 shows the casing 3 in longitudinal section, in order to show the assembly of parallel tubes 2 therein. The two ends of the assembly of parallel conduits 2 are each fixed to a support plate 4 which has a plurality of holes for positioning the respective conduits 2. Each support plate 4 is assembled at the corresponding of the casing 3.

In this embodiment, the casing 3 comprises at each of the two ends thereof a gas reservoir 5 which is assembled on the gas recirculation conduit, although it would also be possible to use a connection flange and a gas reservoir. The casing 3 also comprises an inlet conduit 6 and an outlet conduit 7 of the cooling circuit.

In order to improve the heat exchange and the mechanical strength of the exchanger 1, there are used fins 9 which are arranged inside the tubes 2, as can be seen in FIG. 3.

Furnace soldering of the assembly formed by the tubes 2, the casing 3 and the fins 9 is carried out after complete assembly of the various components of the exchanger 1. The quality of the final furnace welding will be appropriate only on the condition that complete contact of the components is ensured during the furnace-soldering process.

In the same manner, the tubes 2 and the casing 3 comprise a plurality of protuberances 10 and 11, respectively, whose distribution pattern and dimensions are defined in accordance with the dimensions of the tubes 2 and the casing 3 and which are capable of ensuring appropriate distribution of the compression between the casing 3, the tubes 2 and the fins 9 relative to one another during assembly and furnace soldering of the exchanger 1.

Two embodiments of protuberance patterns on the tubes 2 and the casing 3 are described below, respectively. In these instances, the protuberances 10, 11 are produced by means of stamping and have a circular configuration. Each protuberance 10, 11 comprises a substantially planar and circular protruding contact surface 12 and a frustoconical side which is defined by a stamping angle A and connection radii RR relative to said contact surface 12 and to the surface of the tube 2 or casing 3 where the protuberance 10, 11 is stamped.

The dimensions of the protuberances 10, 11 of the tubes 2 and the casing 3, respectively, are defined by their diameter D and height H, the stamping angle A and the connection radii RR at the frustoconical side.

According to a first embodiment for the tube 2 illustrated in FIGS. 4 to 7, a tube 2 has been illustrated with a single row of protuberances 10.

The definition of the protuberance pattern 10 is determined by the following geometric relationships:

H=(1 to 4)×T1
D=(0.1 to 0.5)×W1 and/or D=(0.06 to 0.4)×DD
RR=(0.5 to 2)×T1 and/or RR=(0.1 to 0.6)×H
45°≤A≤75°
DD=(0.05 to 0.6)×L1
DDE=(0.05 to 0.6)×L1
Position of a row of protuberances 10 carried by the longitudinal line of symmetry of the tube 10 mm.

Protuberances distributed over a row if: 10≤W1≤30 mm
Protuberances distributed over two rows if: 26≤W1≤45 mm
where:
H: Height of the protuberance 10
D: Diameter of the contact surface 12 of the protuberance 10
RR: Connection radius relative to the contact surface 12 and to the surface of the tube 2
A: Stamping angle of the protuberance 10
T1: Thickness of the tube 2
W1: Width of the tube 2
L1: Length of the tube 2
DD: Distance between protuberances 10 of the same row
DDE: Distance between the centre of the first protuberance 10 of a row and an of the tube 2.

According to a first embodiment for the casing 3 illustrated in FIGS. 8 and 9, a casing 3 has been illustrated with a single group of two rows of protuberances 11.

The definition of the protuberance pattern 11 is determined by the following geometric relationships:

P=(1 to 4)×T2
D=(0.1 to 0.5)×W1
RR=(0.5 to 2)×T2 and/or RR=(0.1 to 0.6)×H
DD=(0.05 to 0.6)×L2
DDE=(0.05 to 0.6)×L2
Position of a row of protuberances 11 centred on the longitudinal axis of symmetry of the casing±10 mm.
where:
P: Depth of the protuberance 11
H: Height of the protuberance 11
D: Diameter of the contact surface 12 of the protuberance 11
RR: Connection radius relative to the contact surface 12
T2: Thickness of the casing 3
W1: Width of the tube 2
L2: Length of the casing 3
DD: Distance between protuberances 11 of the same row
DDE: Distance between the centre of the first protuberance 11 of a row and an of the casing 3.

According to a second embodiment for the tube 2 illustrated in FIGS. 10 to 13, a tube 2 has been illustrated with two rows of protuberances 10 which are mutually parallel.
Likewise, between the two rows of protuberances on the tubes are two reinforcement protuberances which have a rectangular configuration with two semi-circles at the smallest opposing ends.

The definition of the protuberance pattern 10 is determined by the following geometric relationships:

\( H = (1 \times 4) \times T \)  
\( D = (0.1 \times 0.5) \times W1 \text{ and/or } D = (0.06 \times 0.4) \times DD \)  
\( RR = (0.5 \times 2) \times T1 \text{ and/or } RR = (0.1 \times 0.6) \times H \)

Protuberances distributed over a row if:  
\( 10a \times W1 \leq 30 \text{ mm} \)

Protuberances distributed over two rows if:  
\( 26a \times W1 \leq 45 \text{ mm} \)

Number of protuberances: at least 1 protuberance over 100 to 600 mm²

\( DDH = (0.05 \times 0.6) \times L1 \)

\( DDV = (0.2 \times 0.8) \times W1 \)

\( DDE = (0.05 \times 0.6) \times L1 \)

\( DDE1A = (0.05 \times 0.6) \times L1 \)

\( DDE1B = (0.05 \times 0.6) \times L1 \)

Where:

\( HH = \text{Height of the protuberance} \)

\( D = \text{Diameter of the contact surface} \)

\( RR = \text{Connection radius relative to the contact surface} \)

\( DDH = \text{Distance between protuberances} \)

\( DDV = \text{Distance between rows} \)

\( DDE = \text{Distance between the first protuberance} \)

\( DDE1A = \text{Distance between a first centre of an protuberance} \)

\( DDE1B = \text{Distance between a second centre of an protuberance} \)

According to a second embodiment for the casing 3 illustrated in FIGS. 14 and 15, a casing 3 has been illustrated with two groups of two rows of protuberances 11 which are mutually parallel.

Likewise, between the two rows of protuberances of each group are two reinforcement protuberances 11a, which are circular in this instance.

The definition of the protuberance pattern 11 is determined by the following geometric relationships:

\( P = (1 \times 4) \times T2 \)

\( D = (0.1 \times 0.5) \times W1 \)

\( RR = (0.5 \times 2) \times T2 \text{ and/or } RR = (0.1 \times 0.6) \times H \)

\( DDH = (0.05 \times 0.6) \times L2 \)

\( DDV = (0.2 \times 0.8) \times W2 \)

\( DDE = (0.05 \times 0.6) \times L1 \)

\( DDE1 = (0.05 \times 0.6) \times L1 \)

Where:

\( P = \text{Depth of the protuberance} \)

\( H = \text{Height of the protuberance} \)

\( D = \text{Diameter of the contact surface} \)

\( RR = \text{Connection radius relative to the contact surface} \)

\( T2 = \text{Thickness of the casing} \)

W1: Width of the tube 2  
W2: Width of the casing 3  
L2: Length of the casing 3  
DDH: Distance between protuberances 11 of the same row  
DDV: Distance between rows of the same group  
DDE: Distance between the centre of the first protuberance 11 of a row and an of the casing 3  
DDE1: Distance between the centre of an protuberance 11a and an of the casing 3  

It should be emphasised that, although protuberances 10, 11 have been illustrated with a circular configuration, they may also have other shapes, such as an elongate shape with different orientations (see FIGS. 16a to 16c), or be in the form of a cross (FIG. 16d) or of a diamond (FIG. 16e), inter alia.

In the same manner, tests have been carried out with prototypes in order to analyse the relationship between the thickness of the welding material and the distance of the protuberances with respect to the gap which exists in the assembly joint with furnace welding.

It is possible to see the results of a first test in the graph of FIG. 17, which shows the sensitivity of the position of the protuberances 10, 11 by establishing a relationship between the distance between the protuberances and the gap which exists in the assembly joint when the fin 9 is introduced into the tube 2.

The results indicate that, if the distance between protuberances is reduced, deformations are prevented during the assembly process (deformation of the tube 2) by means of which a smaller size of the gap between the tubes 2 and the fins 9 is obtained. The maximum permissible gap in this technology is 0.15 mm, which corresponds to a distance between protuberances of 40 mm. The greater the dimension of the gap, the more significant the furnace soldering defects and the more the mechanical strength is reduced.

It is possible to see the results of a second test in the graph of FIG. 18, which shows the sensitivity of the thickness of the welding material, by establishing a ratio between the thickness of the welding material and the gap existing in the assembly joint when the fin 9 is introduced into the tube 2.

The results indicate that the larger the dimensions of the gap, the greater the thickness of the required welding material and, consequently, the more expensive the product. The maximum permissible gap in this technology is 0.15 mm, which corresponds to a distance of the thickness of the welding material of 50 micrometres.

1. A heat exchanger (1) for exhaust gases of an engine, the heat exchanger (1) comprising a plurality of parallel tubes (2) which are arranged inside a casing (3) and via which the gases to be cooled by means of heat exchange with a cooling fluid circulate, and fins (9) which disrupt the flow of gas and which are arranged inside each tube (2), wherein the tubes (2) and the casing (3) comprise a plurality of protuberances (10) and (11), respectively, whose distribution pattern and dimensions are defined in accordance with dimensions of the tubes (2) and the casing (3), and which are capable of ensuring appropriate distribution of the compression between the casing (3), the tubes (2) and the fins (9) with respect to one another during furnace soldering of the heat exchanger (1).

2. The heat exchanger (1) according to claim 1, wherein the protuberances (10, 11) are produced by means of stamping, each protuberance (10, 11) comprising a protruding contact surface (12) which is substantially planar and circular and a
frustoconical side defined by a stamping angle (A) and connection radii (RR) relative to said contact surface (12) and to the surface of the tube (2) or the casing (3) where the protuberance (10, 11) is stamped.

3. The heat exchanger (1) according to claim 2, wherein the dimensions of the protuberances (10, 11) of the tubes (2) and the casing (3), respectively, are defined by their diameter (D) and their height (H) and the stamping angle (A) and the connection radii (RR) at the frustoconical side.

4. The heat exchanger (1) according to claim 1, wherein the distribution pattern of the protuberances (10) on the tubes (2) is defined in accordance with the thickness (T1), the width (W1) and the length (L1) of the tube (2), and the protuberances (11) on the casing (3) having a substantially rectangular cross-section and being provided with two opposing flat sides (W1) which are wider than they are high.

5. The heat exchanger (1) according to claim 4, wherein the protuberances (10) are arranged on the two opposing flat sides of the tubes (2), directed towards the outside of the tube (2) and distributed over one or more longitudinal rows in accordance with the width (W1) of the tube (2).

6. The heat exchanger (1) according to claim 1, wherein the protuberances (10) of the same row on the tubes (2) are spaced apart by a predetermined distance (DD, DDH) defined by the length (L1) of the tube (2), and the first protuberance (10) of the corresponding row is arranged relative to an of the tube (2) at a predetermined distance (DDE) which is also defined by the length (L1) of the tube (2).

7. The heat exchanger (1) according to claim 5, wherein the protuberances (10) on the tubes (2) are distributed over two parallel, longitudinal rows which are equidistant relative to a longitudinal axis of symmetry and spaced apart by a predetermined distance (DDV) which is defined in accordance with the width (W1) of the tube (2).

8. The heat exchanger (1) according to claim 7, wherein between the two rows of protuberances (10) on the tubes (2) there are two reinforcement protuberances (10a) which are each located relative to the opposing ends of the tube (2) at a predetermined distance (DDE1, DDE2) defined by the length (L1) of the tube (2).

9. The heat exchanger (1) according to claim 1, wherein the distribution pattern of the protuberances (11) on the casing (3) is defined in accordance with a width (W1) and thickness (T2) of the tube (2), a width (W2) and length (L2) of the casing (3), with the casing (3) having a substantially rectangular cross-section.

10. The heat exchanger (1) according to claim 9, wherein the protuberances (11) are arranged on at least one side of the casing (3), directed towards the inside of the casing (3) and distributed in one or more groups of two longitudinal rows in accordance with the width (W2) of the casing (3).

11. The heat exchanger (1) according to claim 10, wherein the protuberances (11) of the same row are spaced apart by a predetermined distance (DD, DDH) which is defined by the length (L2) of the casing (3) and the first protuberance (11) of the corresponding row is arranged relative to one of the casing (3) at a predetermined distance (DDE) which is also defined by the length (L2) of the casing (3).

12. The heat exchanger (1) according to claim 1, wherein the protuberances (11) are distributed in two groups of two parallel, longitudinal rows which are spaced apart by a predetermined distance (DDV) defined in accordance with the width (W2) of the casing (3), and the two groups of two rows are arranged so as to be equidistant relative to the longitudinal axis of symmetry.

13. The heat exchanger (1) according to claim 12, wherein between the two rows of protuberances (11) of each group there are two reinforcement protuberances (11a) which are each located relative to the opposite ends of the casing (3) at a predetermined distance (DDE1) which is defined by the length (L2) of the casing (3).

14. The heat exchanger (1) according to claim 1, wherein the protuberances (10, 11) may have different shapes such as, circular, cross-like, diamond-like or linear.

15. The heat exchanger (1) according to claim 2, wherein the distribution pattern of the protuberances (10) on the tubes (2) is defined in accordance with the thickness (T1), the width (W1) and the length (L1) of the tube (2) itself, the tubes (2) having a substantially rectangular cross-section and being provided with two opposing flat sides (W1) which are wider than they are high.

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