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(54) **PLATE HEAT EXCHANGER AND METHOD FOR PRODUCING SAME**

(71) Applicant: **Bosal Emission Control Systems NV**, Lummen (BE)

(72) Inventors: **Freddy WOLLANTS**, Aarschot (BE); **Martijn LUYCK**, Hasselt (BE); **Jean-Paul Hubert JANSSENS**, Leopoldsburg (BE); **Bert VERWIMP**, Herentals (BE)

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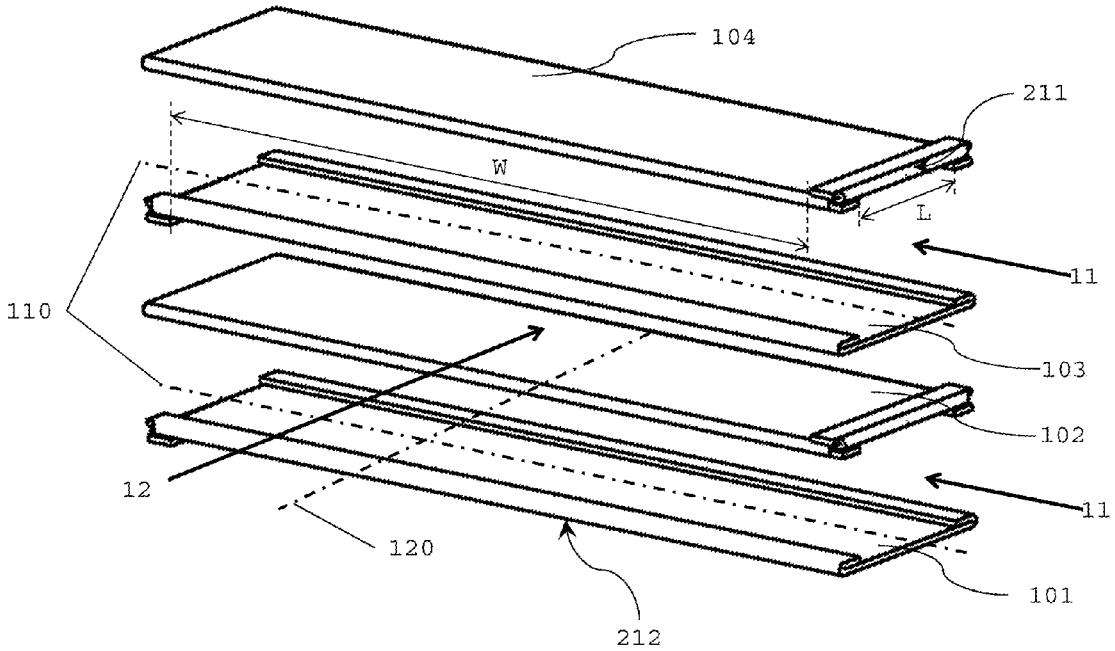
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(57) **ABSTRACT**

A plate heat exchanger comprises a stack of rectangular heat transfer plates, wherein each rectangular heat transfer plate comprises a circumference with four circumference edges arranged at the circumference of the rectangular heat transfer plate, a rectangular heat transfer wall extending between the circumference edges of the heat transfer plate, the rectangular heat transfer wall defining a plane and comprising a circumference portion extending to the circumference edge in the plane of the heat transfer wall, and the heat transfer plate further comprises at least two folded parts arranged at the circumference of the heat transfer plate and extending from the heat transfer wall over the circumference edge of the heat transfer plate, the folded parts contacting the heat transfer wall for forming spacer elements. Two opposite folded parts are folded towards a same side of the plane of the rectangular heat transfer wall, or at least two adjacent folded parts of the rectangular heat transfer wall are each folded towards opposite sides of the plane of the rectangular heat transfer wall with respect to the adjacent folded part. Pairs of heat transfer plates are arranged so that each folded part of one heat transfer plate is in contact over the entire length of the corresponding circumference edge either with a folded part of an adjacent heat transfer plate or with a circumference portion of the heat transfer wall of an adjacent heat transfer plate.



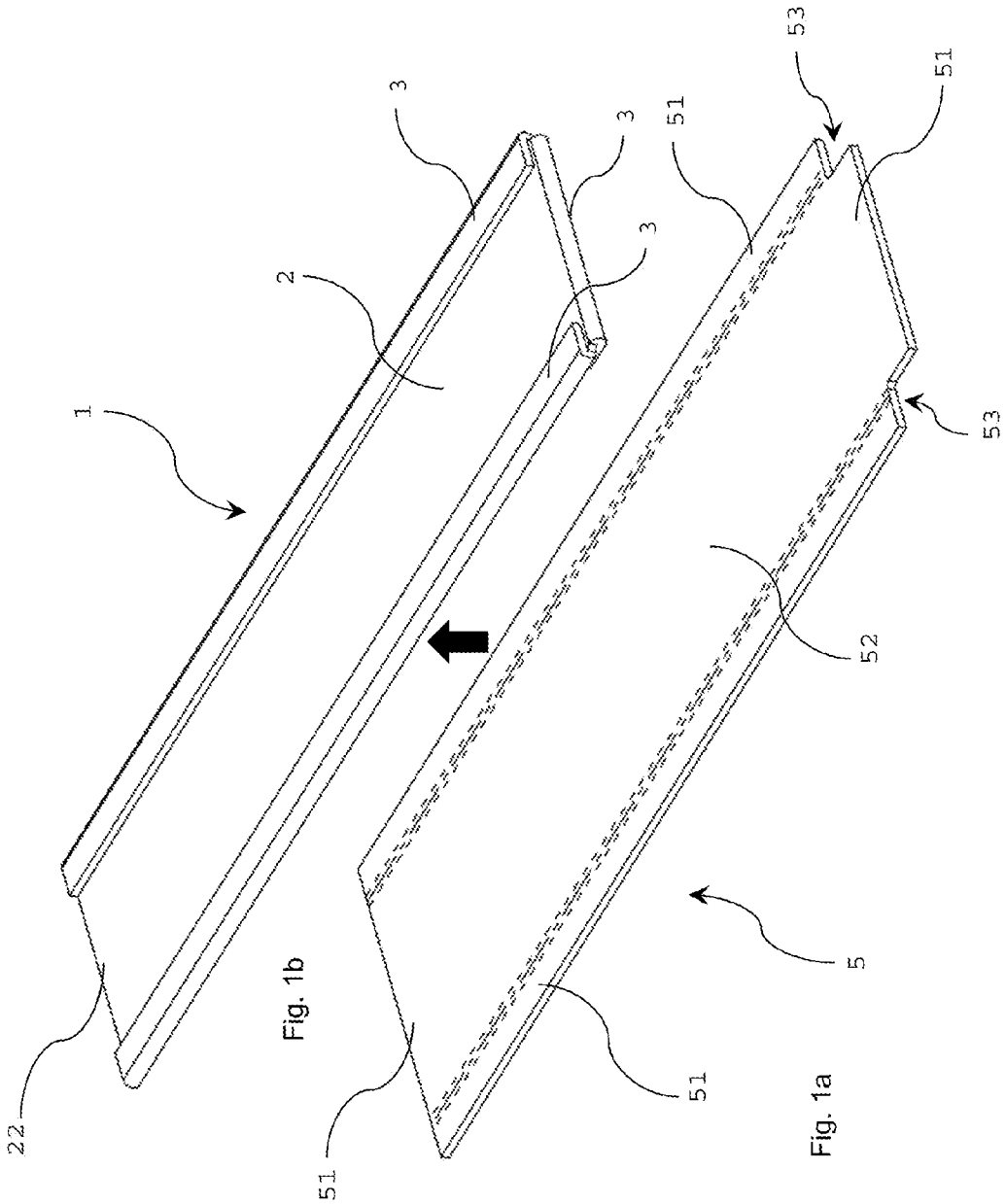


Fig. 1b

Fig. 1a

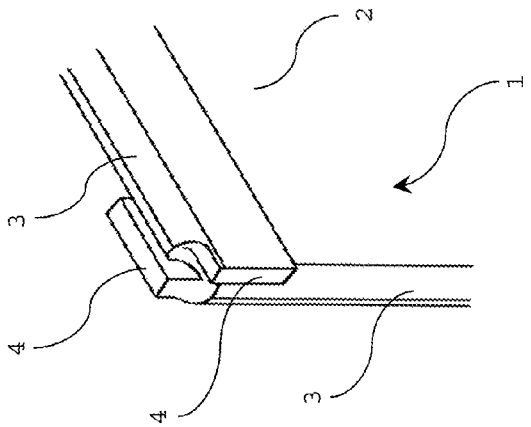


Fig. 3

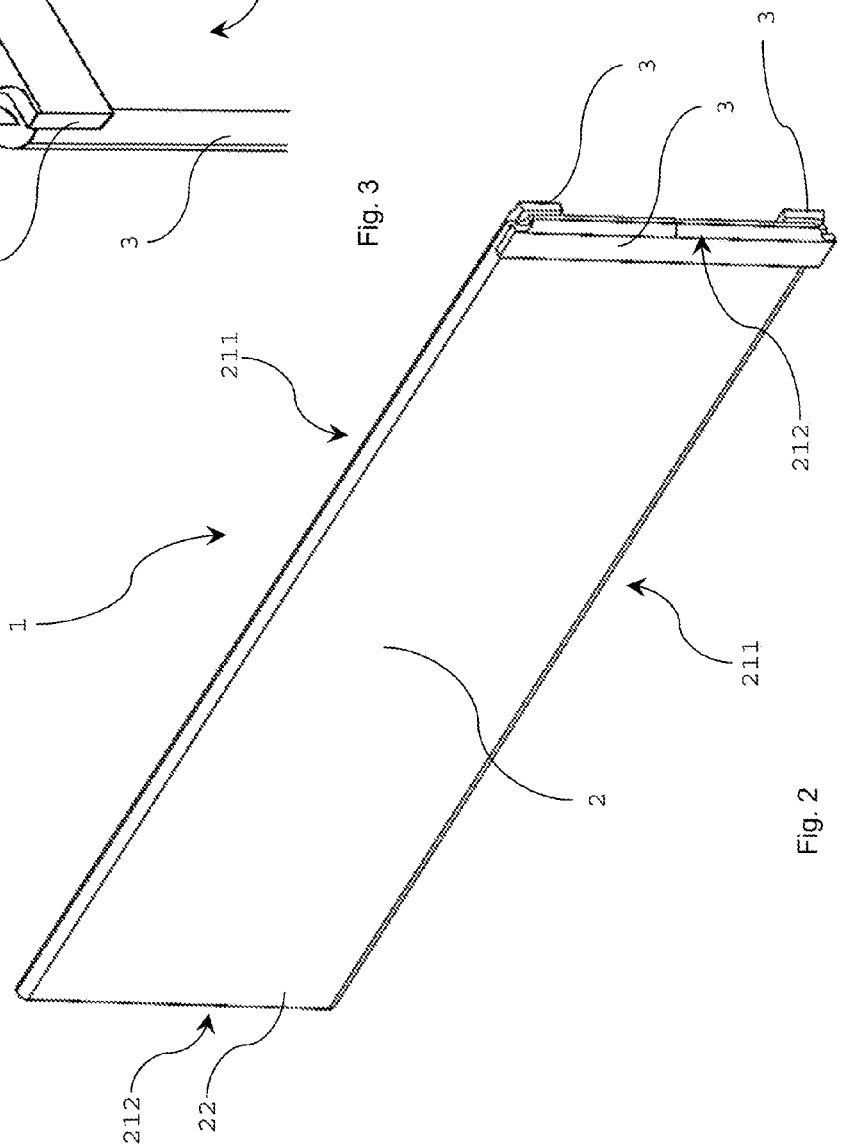


Fig. 2

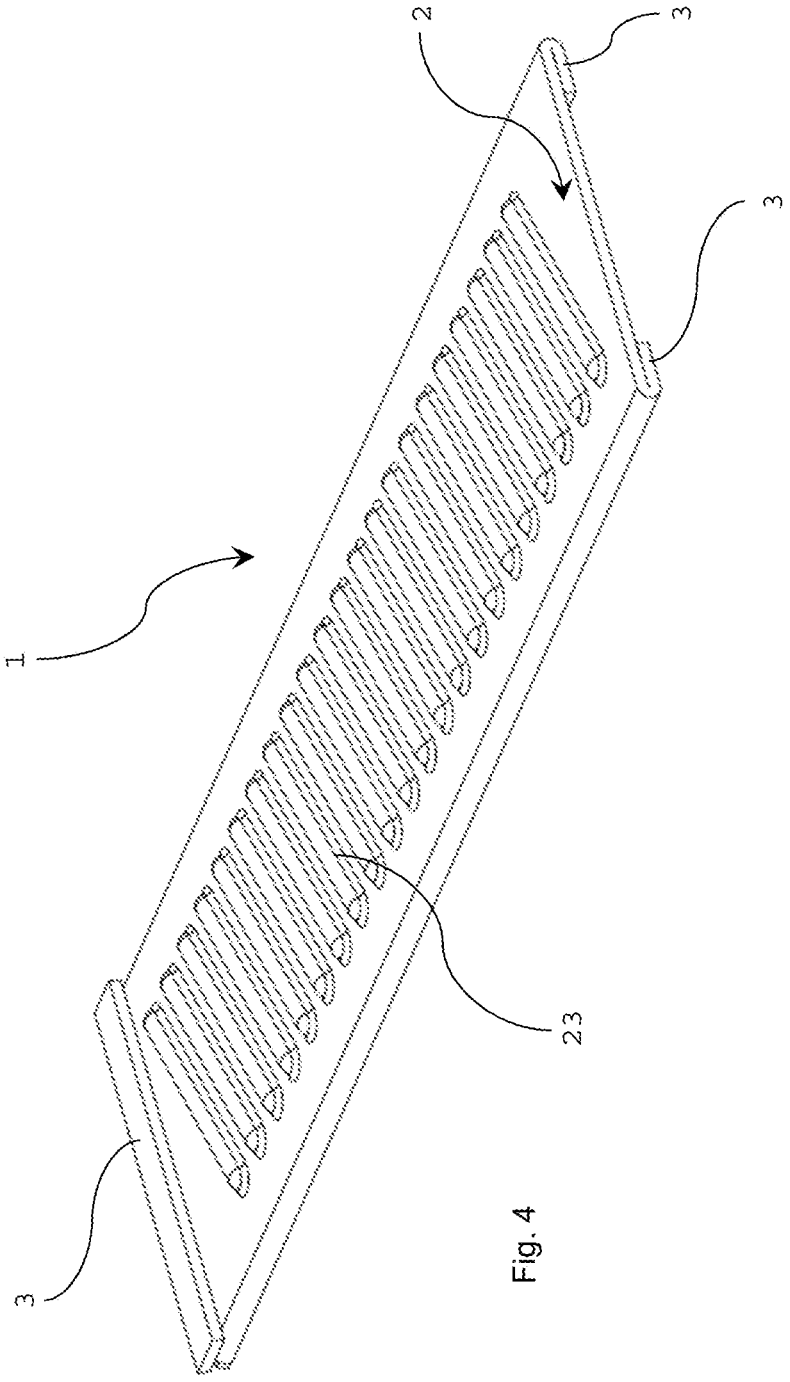


Fig. 4

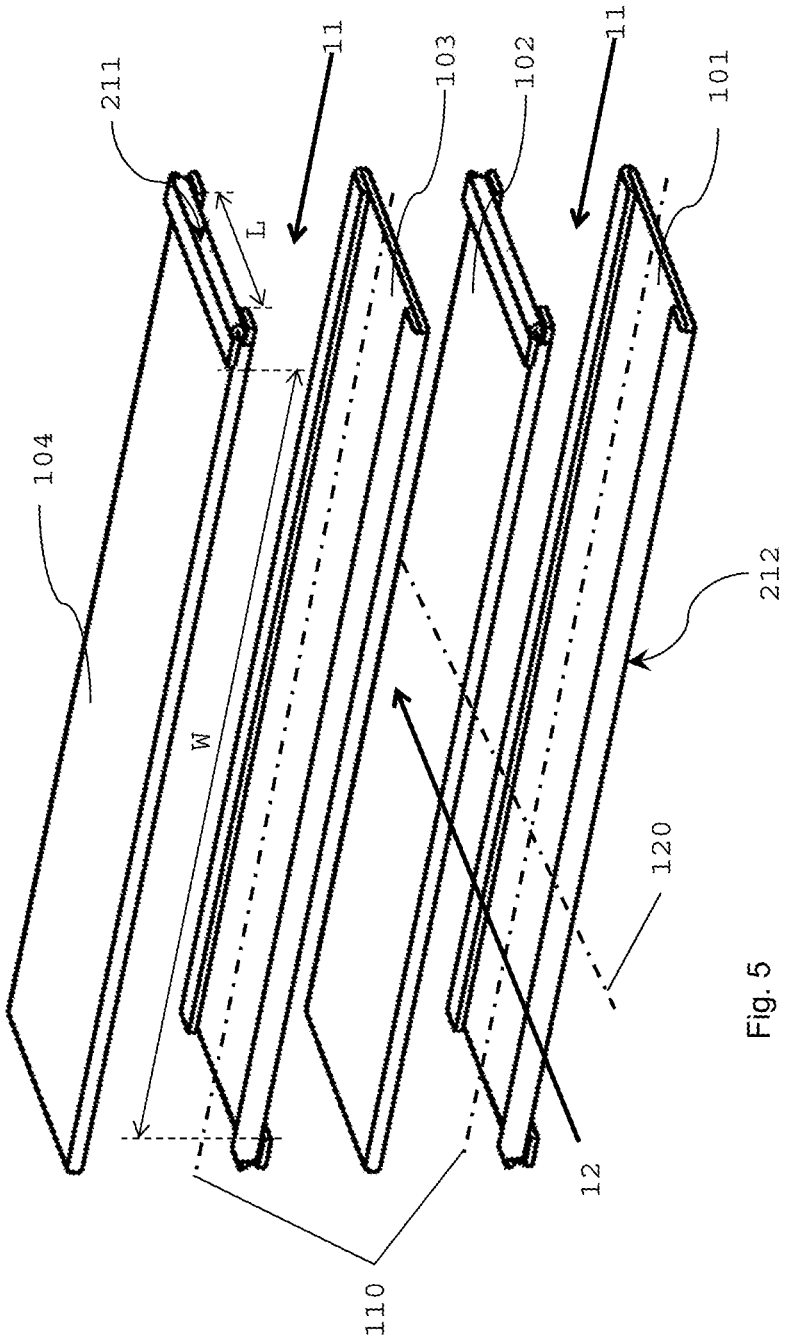


Fig. 5

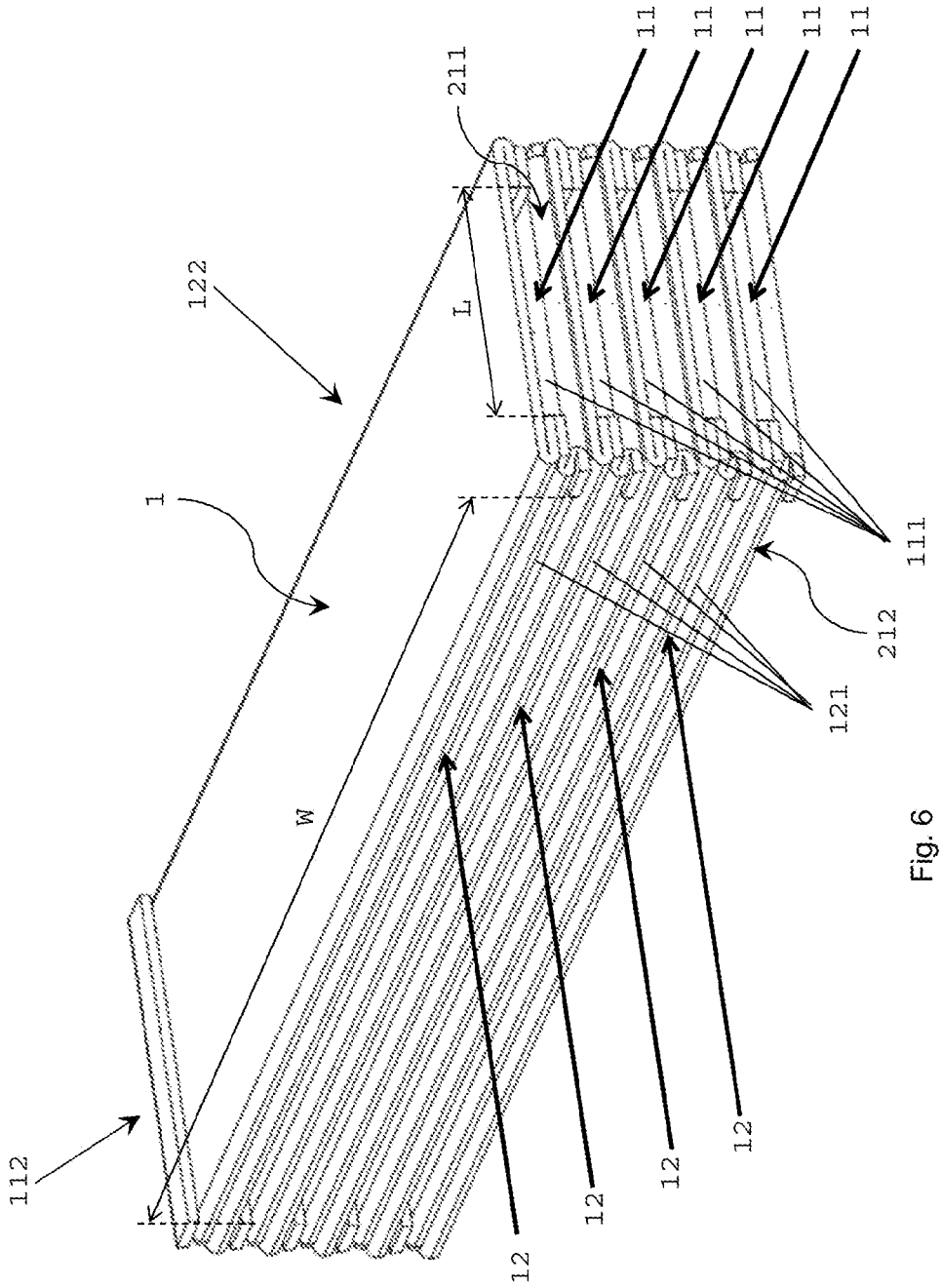


Fig. 6

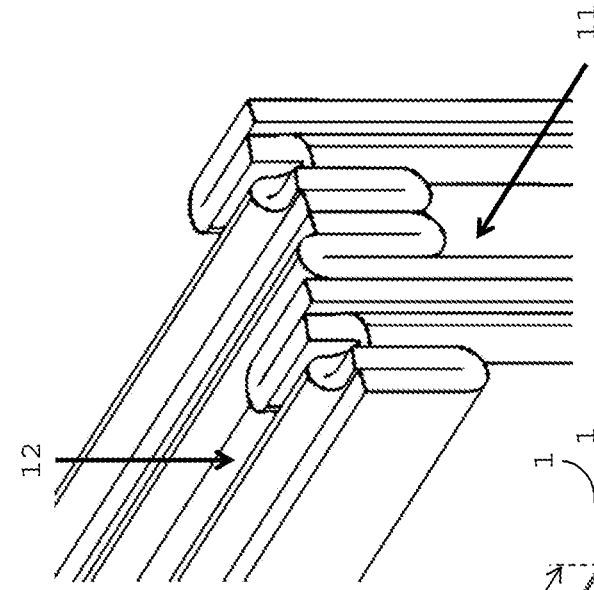


Fig. 8

Fig. 7

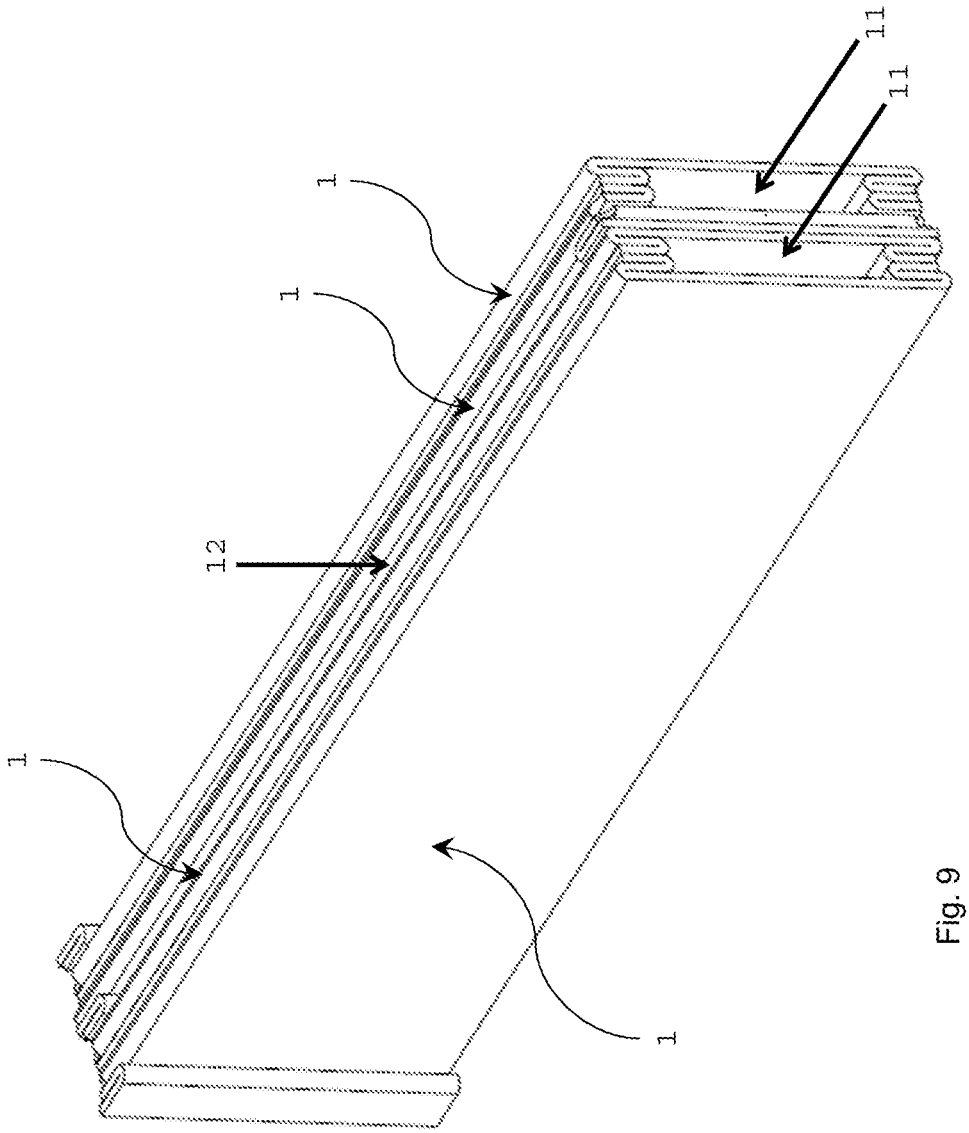


Fig. 9

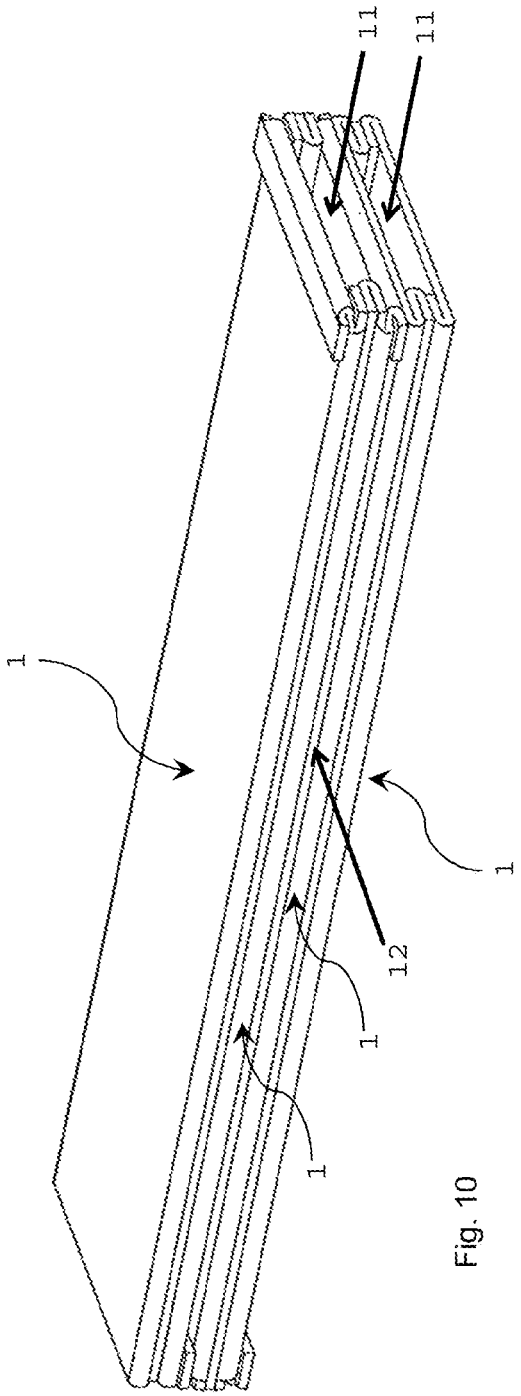


Fig. 10

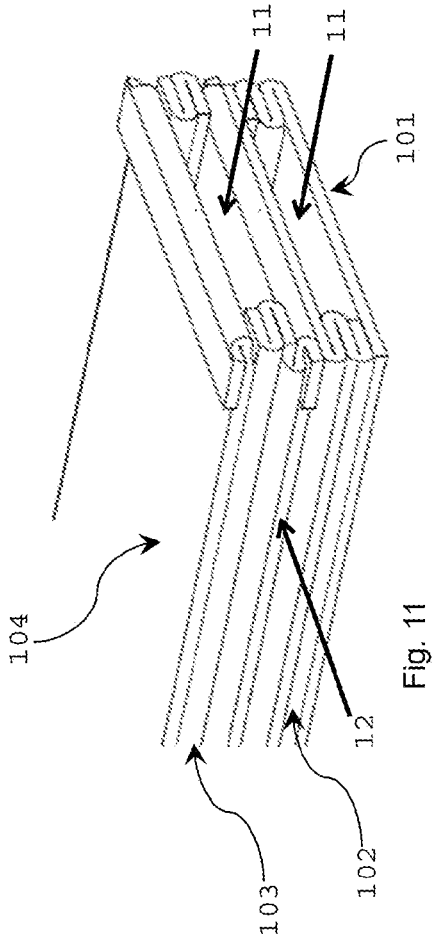


Fig. 11

PLATE HEAT EXCHANGER AND METHOD FOR PRODUCING SAME

[0001] This application claims benefit of Ser. No. 15/185,125.0, filed on 14 Sep. 2015 in the European Patent Office and which application is incorporated herein by reference. To the extent appropriate, a claim of priority is made to the above disclosed application.

[0002] The invention relates to a plate heat exchanger and a method for producing same. In particular, the invention relates to a plate heat exchanger for gas-liquid heat exchange and a method for producing same.

[0003] The automotive industry is more and more oriented in the design of engines, on-board systems and the vehicle itself, towards the reduction of fuel consumption, emission of pollutants, recyclability of materials and the recovery and conversion of thermal energy that would otherwise be dissipated.

[0004] As regards the recovery and conversion of thermal energy, the exhaust gas exiting from the internal combustion engine carries, after being treated by a catalyst or by a more complex treatment unit, an amount of thermal energy that can be recovered for various useful purposes. For example, it has been suggested to recover the thermal energy from the exhaust gas for the purpose of heating the cabin (by more rapidly heating up the cooling water of the engine) of the vehicle, for more rapidly heating up the lubricating oil to the optimum temperature (lower viscosity) after a cold start of the engine, or for converting the thermal energy into electrical energy (with the aid of a suitable converter).

[0005] In an exhaust gas heat recovery system (EGHRS), for example, heat from vehicle exhaust gases may be transferred to other vehicle components via a liquid coolant in order to provide faster heating of air and vehicle fluids on start-up of the vehicle, thereby reducing fuel consumption. Air heated by the exhaust gases can be used for rapid heating of the passenger compartment and for window defrosting, reducing the need for long idling periods during start-up in cold weather. This is an essential need with upcoming hybrid cars, in which, despite fully charged batteries, the combustion engine has to be run on start-up of the vehicle for heating of the passenger cabin and stops once the desired heat is reached and the vehicle is then driven by the electric engine powered by the charged batteries. Hence, the faster the cabin can be heated, the sooner the combustion engine may be shut off. Additionally, heating of vehicle fluids such as engine oil and transmission fluid makes them less viscous and improves fuel economy during start-up.

[0006] Heat recovery components are particularly arranged comparatively close to the engine where the temperature of the exhaust gas stream is very high in order to use the thermal energy (heat) contained in the exhaust gas stream as effectively as possible.

[0007] Due to the very limited space both in the engine compartment but even more in the tunnel provided in the chassis of the motor vehicle, there is extremely limited space available for accommodating the components of the exhaust gas system. Accordingly, the more voluminous the component is the more difficult it is to arrange the component in the engine compartment or in the "tunnel" provided in the chassis of the motor vehicle.

[0008] For enhancing the efficiency of heat exchangers, the heat transfer plates are required to be thin as the heat is guided more efficiently through thin walls. Additionally, thin walls reduce the total weight of the heat exchanger which heats up faster (lower thermal inertia of the heat exchanger) and less weight is to be transported.

[0009] However, reducing the thickness of heat transfer walls has a negative impact on the stability of the walls, as they are easily bent under the influence of uneven heating or forces applied during the manufacturing process, thus reducing the height of the adjacent heat transfer channel, leading to non-uniform fluid flow through the channels and having a negative impact on back pressure. Small differences in height of the channels may result in large differences of backpressure in the individual channels. Therefore, adjacent channels may have varying channel heights leading to non-uniform distribution of the fluid flow through the channels for heat exchange. Each channel is conceived for a specific heat energy transfer, particularly by adjusting the channel height for a specific fluid flow, for optimized efficiency. Due to an uneven height distribution between the individual channels, some channels will have less fluid flow passing than designed for, leading to an inefficient heat transfer. Other channels will have more fluid flow passing the channels faster than designed for, resulting in fluid leaving the channel without completed heat transfer, hence loosing heat energy. The efficiency of such heat exchangers therefore may dramatically decrease due to the bending of the heat transfer walls.

[0010] As known in the art, the plates of heat exchanger are pressed at their edges in direction of the plane of the heat transfer plate to get peaks which contact peaks of adjacent plates. However, this process leads to high tolerance which are nor suitable for efficient function of the heat exchanger.

[0011] Alternatively, the heat transfer plates are separated with the aid of inserts, spacers or other components formed by a mechanical operation, as for example in EP 1 373 819 A1. Again, the tolerance between the separated heat transfer plates using such spacers for such small heights is still too imprecise for efficient function of the heat exchanger. These tolerances are engendered on one hand by the cutting techniques of the spacers deforming the edges of the spacers. On the other hand, these tolerances are generated by the welding of the spacers on the heat transfer plate leading to distortions of the heat transfer plate.

[0012] DE 103 02 948 A1 discloses a heat exchanger, especially a charge air cooler or exhaust gas cooler for motor vehicles. The gas is directed through tube bottoms into an inlet diffuser and an outlet diffuser while the coolant is directed through the housing of the heat exchanger. The flow ducts for the gas and the coolant are formed by a metal strip that is reshaped in a meandering manner and the housing, which are integrally bonded.

[0013] US 2013/0213623 A1 discloses a tube for a heat exchanger which comprises a plate provided with a plurality of parallel flow ports, wherein the plate is formed by a single folded-up metal sheet and consists of an envelope formed by a first portion of the metal sheet, and of a partition structure formed by a second portion of the metal sheet, which extends in an corrugated manner within the envelope so as to define said flow ports therewith, and having connection segments interconnecting opposite walls of the envelope and being interposed between adjacent flow ports.

[0014] Therefore, there is a need for a plate heat exchanger and method for producing same with improved backpressure compared to the prior art heat exchanger. In particular, there is need for a plate heat exchanger and method for producing same having reduced tolerances between individual plates.

[0015] In particular, the plate heat exchanger for gas-liquid heat exchange according to the invention comprises a stack of rectangular heat transfer plates,

[0016] wherein first and second flow channels are arranged alternately between the heat transfer plates of the stack, with every first flow channel for a through-flow of a first fluid and every second flow channel for a through-flow of a second fluid,

[0017] wherein each rectangular heat transfer plate comprises a circumference with four circumference edges arranged at the circumference of the rectangular heat transfer plate, a rectangular heat transfer wall extending between the circumference edges of the heat transfer plate, the rectangular heat transfer wall defining a plane and comprising a circumference portion extending to the circumference edge in the plane of the heat transfer wall, and the heat transfer plate further comprises at least two folded parts arranged at the circumference of the heat transfer plate and extending, preferably bent or folded, from the heat transfer wall over the circumference edge of the heat transfer plate, the folded parts contacting the heat transfer wall for forming spacer elements,

wherein two opposite folded parts are folded from the heat transfer wall towards a same side of the plane of the rectangular heat transfer wall, or at least two adjacent folded parts of the rectangular heat transfer wall are each folded from the heat transfer wall towards opposite sides of the plane of the rectangular heat transfer wall with respect to the adjacent folded part, and

wherein pairs of heat transfer plates are arranged so that each folded part of one heat transfer plate is in contact, particularly over the entire length of the corresponding circumference edge, either with a folded part of an adjacent heat transfer plate or with a circumference portion of the heat transfer wall of an adjacent heat transfer plate,

[0018] The circumference edges may comprise two length side edges and two width side edges, and the plate heat exchanger may comprise first inlet and outlet openings formed by corresponding pairs of heat transfer plates and arranged at the length side edge and second inlet and outlet openings formed by corresponding pairs of heat transfer plates and arranged at the width side edge.

Particularly, the length of each second inlet and outlet opening at the width side edges is larger than the length of each first inlet and outlet opening at the length side edges.

[0019] In particular, the folded parts are folded onto the heat transfer wall and contacting the heat transfer wall. The heat transfer plate is particularly an elongated rectangular heat transfer plate.

[0020] The length of the inlet and outlet openings is the length measured along the corresponding side edge (length or width side edge) from one folded part to the other folded part delimiting the corresponding inlet and outlet openings.

[0021] The plate heat exchanger according to the present invention has improved flow channel height tolerances, the flow channel height being the distance between the surface of one heat transfer wall to the adjacent surface of the heat transfer wall of the adjacent heat transfer plate (the length of the perpendicular distance from the surface of one heat transfer wall to the adjacent surface of the heat transfer wall of the adjacent heat transfer plate). Indeed, the spacer separating one heat transfer wall from the other is formed by folding a metal sheet in such a way, that the thickness of the folded part corresponds to the number of folds of the metal sheet times the thickness of the metal sheet. The tolerances of industrially available metal sheets are very low and the thickness accuracy of the available metal sheets very high over the surface of the metal sheet. Additionally, the manufacture of the folded parts in the folding process is very accurate and no distortion of the heat transfer wall will occur by welding or other metal-joining techniques such as brazing or fusion bonding. The folded parts along the circumference edges of the heat transfer wall will also stabilize the heat transfer plate due to the rigid edge.

[0022] Hence, the resulting folded parts have excellent tolerances and will lead to uniform heights of the flow channels within the flow channels and from one flow channel to the other. Furthermore, the folded parts will reduce the distortions of the heat transfer wall as the folded edges are stiffer than spacers welded or brazed onto edges. This is due to the inherent stiffness of folded edges and because a spacer can be bent or deformed during its manufacturing process before it is placed on the heat exchanger plate.

[0023] The friction of the fluid flowing through a flow channel of a plate heat exchanger is proportional to the third power of the hydraulic diameter of the flow channel. Therefore, the height of the flow channel has an impact on the amount of fluid passing the channel. A uniform flow channel height of all the flow channels through which a fluid is flowing dramatically therefore improves the efficiency of the plate heat exchanger, as small differences in the height of the flow channel results in large flow amount variations of the fluid through the different flow channels. The plate heat exchanger according to the invention therefore improves the efficiency of the plate heat exchanger

[0024] Additionally, the plate heat exchanger according to the invention allows the use of thin heat transfer plates. Indeed, although thin heat transfer walls are more easily deformed than thick walls under the influence of uneven heating or forces during the manufacturing process, resulting in deformed plates which also reduce the height of flow channels. As discussed previously, the present invention effectively reduces these deformations.

[0025] The thin heat exchanger plates result in a more efficient transfer of the thermal energy from the first fluid through the heat transfer wall into the second fluid. Furthermore, the thickness of the walls has a direct impact on the weight of the plate heat exchanger. Additionally, thin walls have less heat inertia and will therefore heat up faster.

[0026] Furthermore, the plate heat exchanger according to the present invention does not need any separate spacer elements which would have to be welded to the heat transfer plates, hence being more complex in manufacturing and may lead to additional defects.

[0027] Heat transfer plates having two adjacent folded parts of the rectangular heat transfer wall will have enhanced stiffness due to the excellent rigidity in the two directions of the plane of the heat transfer wall.

[0028] Due to the high density difference between a liquid and a gas, a width of each rectangular heat transfer plate being larger than the length of each rectangular heat transfer plate will reduce the pressure drop of the gas flowing along the path formed from one wide side edge to the second wide side edge. On the other side, the liquid velocity being low due to the inherent high density of the liquid when compared to the gas, pressure drop will not be as severe as for the gas and therefore may pass along the flow path formed from one length side edge to the second length side edge.

[0029] Overall, the plate heat exchanger according to the invention is particularly efficient, fuel-saving and compact.

[0030] The folded parts project from the heat transfer wall. To this purpose, the edge portions of the metal sheet the heat transfer plate is made of are folded onto the heat transfer wall of the heat transfer plate over the circumferential edge of the heat transfer plate. The folded parts are an integral part of the metal sheet the heat transfer plate is made of.

[0031] According to another aspect of the plate heat exchanger according to the invention, the length of each second inlet and outlet opening is at least 2 times larger, particularly at least 2.5 times larger, very particularly at least 3 times larger than the length (L) of each first inlet and outlet opening. In particular, the length of each second inlet and outlet opening is no more than 10 times larger, particularly no more than 7 times larger than the length (L) of each first inlet and outlet opening.

[0032] According to another aspect of the plate heat exchanger according to the invention, the total number of folds of the folded parts separating the respective heat transfer walls on the width side edges and forming the first inlet and outlet openings is larger than the total number of folds of the folded parts separating the respective heat transfer walls on the length side edges and forming the second inlet and outlet openings.

[0033] This particular arrangement allows for particularly high stiffness along the wide side edge, particularly prone to bending, as the total number of folds of the folded parts is higher than for the length side edge. The total number of folds has a huge impact on the stiffness of the heat transfer plate along the corresponding edge. Due to the width of the wide side edge being larger than the length of the length side edge, the heat transfer plates are particularly prone to bending along the wide side edge when compared to the length side edge. Additionally, as the channel height on the wide side is smaller than on the length side due to the specific combination of the total number of folds, lower tolerance is allowed than for the channel height along the length side. Finally, when the hot gas passes the channel along the wide side, the wide side edges are exposed to higher temperatures than the length side edges passed by the liquid to be heated, hence again leading to higher strain forces inducing potential plate bending. Due to these reasons, a particularly high stiffness is required.

[0034] Additionally, due to the length of each second inlet and outlet opening at the width side edges being larger than the length of each first inlet and outlet opening at the length side edges, it is particularly advantageous to have a channel height from the first inlet and outlet openings larger than the channel height from the second inlet and outlet openings.

[0035] These properties are specifically obtained by adjusting the number of folds of the folded parts separating the respective heat transfer walls according to this aspect.

[0036] According to a further aspect of the plate heat exchanger according to the invention, the first flow channels for the first fluid extending from first inlet openings to first outlet openings which are connectable to a first inlet port and a first outlet port respectively and forming a first channel path, and the second flow channels for the second fluid extend from second inlet openings to second outlet openings which are connectable to a second inlet port and a second outlet port and forming a second channel path. Particularly, the first channel path is orthogonal to the second channel path. The channel path is the straight path from the center of the first or the second inlet opening to the center of the respective first or second outlet opening. The first and second inlet openings and outlet openings generally present a substantially rectangular form, therefore, the center of the corresponding opening is the center of the rectangular (intersection of diagonals of rectangle) forming the opening. Of course, the channel path as defined within the framework of the present invention is independent from the actual flow path of the fluid through the corresponding channel in operation.

[0037] In particular, the first flow channels are liquid flow channels extending from the first inlet openings to the first outlet openings and are connectable to a liquid inlet port and a liquid outlet port respectively and forming a liquid channel path, and the second flow channels are gas flow channels extending from the second inlet openings to the second outlet openings and are connectable to a gas inlet port and a gas outlet port and forming a gas channel path.

[0038] This aspect allows for advantageous use of the plate heat exchanger for efficient transfer of thermal energy from one fluid into the other. In particular, the first fluid is gaseous, in particular an exhaust gas from an engine with internal combustion, and the second fluid is a coolant liquid, particularly from the cooling circuit of an engine with internal combustion.

[0039] In accordance with a further aspect of the heat recovery component according to the invention, at least one folded part has two or more folds folded onto each other.

[0040] Particularly, the number of folds of the folded parts varies from one folded part to the other.

[0041] This aspect of the invention allows using the present plate heat exchanger in a very flexible manner by adapting the heights of the flow channels to the respective needs. For example, depending on the thickness of the heat transfer plate, the folded parts will have corresponding thicknesses which may be adapted by the number of folds in each folded part. Furthermore, varying the number of folds from one folded part to the other will vary the height of the flow channel allowing adjusting the flow channel height to the fluid flowing through the flow channel. For example, a liquid may need another flow channel height than a gas.

[0042] In another aspect of the plate heat exchanger according to the invention, the folds of the folded parts are U-shaped and have a 180° turn.

[0043] This aspect is particularly advantageous in that it allows a very compact and yet very efficient and flexible manufacture of the plate heat exchanger according to the invention.

[0044] According to a further aspect of the plate heat exchanger according to the invention, at least three folded parts of the rectangular heat transfer wall are each folded, in an alternating sequence, towards opposite sides of the plane of the rectangular heat transfer wall so that adjacent pairs folded parts are folded towards opposite sides of the plane of the rectangular heat transfer wall.

[0045] This aspect is advantageous since the heat transfer plates have enhanced stiffness due to the excellent rigidity of the at least three bent edges for forming the folded parts. Additionally, this aspect allows the use of one type of heat transfer plates which are stackable for forming the plate heat exchanger, reducing the complexity of the manufacture (only one type of heat transfer plate to be produced for one type of plate heat exchanger) and the complexity and error

rate of the stacking procedure (only one type of heat transfer plate to be stacked for one type of plate heat exchanger).

[0046] In accordance with yet another aspect of the invention, the heat transfer plates are made of a metal sheet having a thickness t and having a shape adapted to form the heat exchanger plate.

[0047] This aspect is advantageous as the shape of the metal sheet allows simple folding of the circumference edge parts.

[0048] Particularly, the metal sheet is rectangular and has four corners, and the metal sheet has cut-out edges on at least one corner of the metal sheet

[0049] The cut-out edges allow for folding of the metal sheet without subsequent manufacturing step.

[0050] According to a further aspect of the invention, the folded parts have a thickness corresponding to the number of folds of the folded part times the thickness t of the metal sheet.

[0051] This aspect is advantageous as it allows a very accurate adjustment of the height of the corresponding flow channel.

[0052] In accordance with still a further aspect of the plate heat exchanger according to the invention, the heat transfer walls are separated by the folded parts by a distance corresponding to the number of folds of the respective folded parts separating the corresponding heat transfer walls times the thickness t of the metal sheet the heat transfer plate is made of.

[0053] In accordance with a further aspect of the plate heat exchanger according to the invention, the heat transfer walls comprise a three-dimensional structure. The three-dimensional structure may have diverse shapes such as corrugations, dimples or chevrons.

[0054] This aspect of the invention presents the advantage of enhancing the stiffness of the heat transfer plate. Another advantage of this aspect is the possibility to guide the fluid flow by the three-dimensional structure of the heat transfer wall.

[0055] In another aspect of the invention, the heat exchanger plates are stacked against each other and joined together by welding, brazing or fusion bonding, particularly by welding, at least on the width side of the heat exchanger plates.

[0056] This aspect allows a very compact and tight construction of the plate heat exchanger according to the invention and ensures sealed heat transfer plates with no leakage. Additionally, the welding of the heat exchanger plates on their width side will further increase the stiffness of the plates along the width side where a bending of the heat exchange plates is less tolerated.

[0057] Particularly, the plate heat exchanger comprises at least one end plate for sealing the plate heat exchanger, allowing the ending of the plate heat exchanger. In particular, such an end plate is needed if the last heat transfer plate shall be used as channel on both sides of its heat transfer walls **2**.

[0058] Particularly the thickness of the metal sheet the heat transfer plate is made of is in the range of from 0.5 mm to 2 mm, particularly from 0.7 mm to 1.3 mm very in particular from 0.75 mm to 1.25 mm.

[0059] This thickness is particularly advantageous with regard to sufficient stiffness of the heat transfer plates and good heat transfer efficiency and weight of the plat heat exchanger.

[0060] The folded parts of the heat transfer plate is preferably manufactured by folding edge portions of the metal sheet and pressing the plate in order to ensure that the folded parts are folded onto and in contact with the heat transfer wall.

[0061] The plate heat exchanger according to the invention is particularly suited for heat transfer from a gaseous fluid, in particular an exhaust gas from an engine with internal combustion to a liquid fluid, in particular a coolant liquid, as, for example typical engine coolants comprising water, antifreeze and additives. Particularly the gaseous fluid passes through the flow channels with larger height than the height of the flow channels through which the liquid fluid flows.

[0062] The invention is further described with regard to embodiments, which are illustrated by means of the following drawings, wherein:

[0063] FIG. **1***a* depicts a metal sheet for forming a heat transfer plate according to the invention;

[0064] FIG. **1***b* illustrates a heat transfer plate according to the invention formed by the metal sheet of FIG. **1***a;*

[0065] FIG. **2** shows an alternative heat transfer plate according to the invention comprising three-dimensional corrugations in the heat transfer wall

[0066] FIG. **3** illustrates a heat transfer plate according to the present invention;

[0067] FIG. **4** shows a magnified portion of the heat transfer plate according to FIG. **1**;

[0068] FIG. **5** is an exploded view of a stack of four heat transfer plates according to the invention;

[0069] FIG. **6** is a view of an assembled stack of 10 heat transfer plates according to the invention;

[0070] FIG. **7** illustrates an assembly of two heat transfer plates according to another embodiment of the invention.

[0071] FIG. **8** shows a magnified portion of the heat transfer plate according to FIG. **6**;

[0072] FIG. **9** depicts another heat transfer plate assembly according to another embodiment of the present invention;

[0073] FIG. **10** depicts a heat transfer plate assembly according to a further embodiment of the present invention;

[0074] FIG. **11** illustrates another embodiment of a heat transfer plate assembly according to the present invention.

[0075] FIG. **1***a* shows an elongated rectangular flat metal sheet **5** for forming a heat transfer plate **1** according to the present invention. In particular, the rectangular flat metal sheet **5** extends in a plane and comprises four edge portions **51** in the plane of the metal sheet and a rectangular center portion **52** extending between the four edge portions forming the heat transfer wall **2** of the heat exchanger plate **1**. The rectangular flat sheet of metal **5** has two cut-out corners **53** for forming the rectangular shape of the heat transfer plate **1** in the folded structure. The metal sheet may also have a three dimensional structure in the rectangular central portion such as corrugations, dimples or chevrons, which will form a three dimensional structure of the heat transfer wall.

[0076] Three of the four edge portions **51** of the metal sheet are folded in opposite direction to one another with respect to the plane of the rectangular metal sheet **5** to form folded parts **3**. The folded parts **3** are contacting the rectangular center portion **52** of the metal sheet forming the heat transfer wall **2** as can be seen in FIG. **1***b*. The folded parts **3** forming spacer elements **4** are arranged on both sides of the plane of the rectangular heat transfer wall **2** formed.

[0077] In FIG. **2**, the elongated rectangular heat transfer plate **1** formed from the metal sheet **5** of FIG. **1** is illustrated in side view. Three adjacent edge parts of the four edge parts **51** of the metal sheet **5** were folded each in opposite direction to one another with respect to the plane of the metal sheet forming the heat transfer wall **2**, thus creating folded parts **3** contacting the heat transfer wall **2**. The folds of the folded parts are U-shaped and have a 180° turn. The formed heat transfer plate has four circumference edges **21**.

[0078] The folded parts **3** are forming spacers **4** on both sides of the plane of the metal sheet **5**, resulting in two opposite folded parts **3** of the metal sheet are folded in the same direction with respect to the plane of the metal sheet and one folded part **3** adjacent to the two other folded parts **3** is folded in the opposite direction with respect to the plane of the metal sheet. The fourth circumference edge of the heat transfer plate is straight and has no folds, therefore left in the plane of the metal sheet **5** forming a circumference portion **22**.

[0079] The folded parts **3** have a thickness, comprising the metal sheet **5** thickness and the fold thickness, along the circumference edge of two times the thickness of the metal sheet (single fold). At the corners of the heat transfer plate, the thickness of two folded portions may add and will therefore have up to three times the thickness of the metal sheet. The formed spacers **4** have a thickness corresponding to one fold forming the spacer **4** corresponding to the thickness of the metal sheet **5**, the heat transfer plate is made of. This assembly can be better seen in FIG. **3** which is a magnification of two folded edges of a plate according to FIG. **2**.

[0080] FIG. **4** shows an alternative to the flat heat transfer wall **2** according to the preceding embodiment shown in FIGS. **1***a*, **1***b* and **2**. The heat transfer plate **1** has corrugations **23** along the heat transfer wall **2** between the folded edges **3**. These corrugations **23** are particularly formed by stamping. The three dimensional structure in the heat transfer wall **2** may have alternative shapes, such as dimples or chevrons.

[0081] In FIG. **5**, an exploded view of a stack of four heat transfer plates according to the invention shown in FIG. **2** is illustrated. The first plate **101** is arranged to have the two opposite folded parts **3** facing the second heat transfer plate **102**. This second heat transfer plate **102** is arranged having the two opposite folded parts **3** facing the first heat transfer plate **101**. In the assembled state, this pair of heat transfer plates **101**, **102** will form a channel **11**, **12** with a precise height of twice the thickness of the metal sheet **5** as two folded parts abut. On the other side, the second heat transfer plate **102** faces a third heat transfer plate **103** which is in the same position than the first heat transfer plate **101**. The second heat transfer plate **102** has a folded part adjacent to the two other folded parts. This side of the heat transfer plate **102** will abut the third heat transfer plate **103**. The third heat transfer plate **103** is arranged facing the second heat transfer plate **102** with its single folded part at the opposite side of the heat transfer plate **103**. In the assembled state, this pair of heat transfer plates **102**, **103** will form a second channel with a precise height of once the thickness of the metal sheet as only one folded part directly abuts the circumferential portion **22** of the respective heat transfer plate **1**.

[0082] The fourth plate **104** is again arranged in the same position than the second plate **102**. Hence, in this embodiment, every heat transfer plate positions are alternating and every second heat transfer plates are arranged in the same position, whereas adjacent heat transfer plates are rotated by 180° along the transversal axis of the heat transfer plate.

[0083] In this arrangement, first and second flow channels **11**, **12** are arranged alternately between the heat transfer plates **101**, **102**, **103**, **104**. Every first flow channel **11** allows a through-flow of a first fluid and forms a first flow path **110** and every second flow channel **12** allows a through-flow of a second fluid and forms a second flow path **120**.

[0084] The dimensions of the heat transfer plates **101**, **102**, **103**, **104** are such that the length W of each second inlet and outlet opening at the width side edges **212** is larger than the length L of each first inlet and outlet opening at the length side edges **211**. In fact, once assembled, in this embodiment the length W will be more than 4 times larger than the length L. Once assembled, the first flow channels **11** have a first channel height corresponding to two times the thickness of the metal sheet the heat transfer plates **101**, **102**, **103**, **104** are made of due to the two single folds along the wide side **212** on each face forming the first flow channels **11**. However, the side edges **211** only comprise one single fold between each heat transfer wall, hence resulting in a second channel height corresponding to one times the thickness t of the metal sheet. On the other hand, the width side edge comprises a total number of folds of the folded parts of two, hence increasing the stiffness of the width side edge **212** along the critical width side and reducing the corresponding bending of the heat transfer plates **101**, **102**, **103**, **104** along this direction. The stiffness of the heat transfer plates **101**, **102**, **103**, **104** is further increased by welding the folded part onto a folded part of an adjacent heat transfer plate **102**, **103**, **104**, **101** or onto a circumference portion of the heat transfer wall of an adjacent heat transfer plate **102**, **103**, **104**, **101**. This welding is particularly efficient along the critical width side of the heat transfer plates **101**, **102**, **103**, **104**.

[0085] FIG. **6** shows a stack of 10 heat transfer plates **1** corresponding to the heat transfer plates **1** as illustrated in FIG. **5**. The heat transfer plates **1** are stacked against each other. The pairs of heat transfer plates **1** are arranged so that the heat transfer walls **2** are separated by the folded parts **3** on two opposite circumferential edges of the heat transfer plate **1** and each folded part **3** of one heat transfer plate **1** is in contact over the entire length of the folded part **3** alternately with a folded part **3** of an adjacent heat transfer plate **1** or with a folded part **3** of an adjacent heat transfer plate **1**. This figure also illustrates the first and second flow channels **11**, **12** are arranged alternately between the heat transfer plates **1**. Every first flow channel **11** allows a through-flow of a first fluid and forms a first flow path **110** and every second flow channel **12** allows a through-flow of a second fluid and forms a second flow path **120**.

[0086] The first flow channels **11** extend from first inlet openings **111** to first outlet openings **112** and form a first flow path **110**, and the second flow channels **12** extend from second inlet openings **121** to second outlet openings **122** form a second flow path **120**. The first flow path **110** is orthogonal to the second flow path **120**. Again, the U-shaped folds having a 180° turn can be seen. The thickness of the flow channels along the short side correspond to the thickness of the metal sheet the heat transfer plate is made of, as all folded parts **3** forming this flow channel include one fold which contacts over its entire length a circumference portion **22** of the heat transfer wall **2** of the adjacent heat transfer plate **1**. The thickness of the channels along the long

elongation of the stack of heat transfer plates correspond to twice the thickness of the metal sheet **5** the heat transfer plate is made of, as the folded parts **3**, including only one fold, contact over their entire length another folded part **3** of the adjacent heat transfer plate **1**. The heat transfer plates **1** according to the present invention allow very precise and uniform spacer element **4** thickness with low tolerances due to the low tolerance of the thickness of the metal sheet **5** used for forming the heat transfer plates **1**. Hence, the channels resulting from stacking several heat transfer plates **2** also have heights with very low tolerances.

[0087] On FIG. **6**, the correlation of the number of folds and the corresponding channel heights discussed for FIG. **5** becomes evident. Although the heat transfer plates **1** only comprise one single fold between the heat transfer walls **2** along the length side **211**, the height of the first flow channel **11** is of two times the thickness t of the metal sheet the heat transfer plate is made of. This is due to the two single folds contacting each other along the width side edge **212** resulting in a total of two folds separating the heat transfer walls. This total of two folds increase the stiffness of the heat transfer plate **1** along the critical direction of the width side edge **212**. However, the one single fold between the heat transfer walls along the length side **211** results in a height of the second flow channel **12** being only one time the thickness t of the metal sheet. Again, the ratio between the length W and the length L is slightly larger than 4 in this embodiment.

[0088] FIG. **7** illustrates another embodiment of the plate according to the present invention, showing an assembly of three heat transfer plates **1**, wherein each plate has folded parts **3** which are folded several times. The folded parts **3** are folded twice on each side with respect to the plane of the rectangular heat transfer wall **2** of the heat transfer plate **1** in the present embodiment. An assembly similar to the preceding embodiment will therefore result in channels having precise heights of twice the metal sheet thickness where the folded part directly abuts the circumferential portion **22** of the heat transfer wall **2** and four times the thickness of the metal sheet **5** where the folded parts **3** each abut another folded part **3** of an adjacent heat transfer plate.

[0089] In this specific embodiment, the length W of each second inlet and outlet opening at the width side edges **212** is slightly more than 4 times larger than the length L of each first inlet and outlet opening at the length side edges **211**. Once the heat transfer plates **1** are assembled, the first flow channels **11** have a first channel height corresponding to four times the thickness t of the metal sheet **5** the heat transfer plates **1** are made of due to the two double folds along the wide side **212** on each face forming the first flow channels **11**. However, the side edges **211** only comprise one double fold between each heat transfer wall, hence resulting in a second channel height corresponding to two times the thickness t of the metal sheet. On the other hand, the width side edge **212** comprises a total number of folds of the folded parts of four, hence increasing the stiffness of the width side edge **212** along the critical width side and reducing the corresponding bending of the heat transfer plates **1** along this direction.

[0090] FIG. **8** is a magnification of the embodiment shown in FIG. **7** wherein the different thicknesses of the folded parts **3** and the corresponding heights of the channels is seen.

[0091] FIG. **9** shows an assembly of four heat transfer plates **1** analogous to the heat transfer plates of FIG. **7**. The first flow channels **11** for a through-flow of a first fluid and second flow channels **12** for a through-flow of a second fluid are shown in this drawing.

[0092] In FIG. **10**, another embodiment of the present invention is shown in which two differently heat transfer plates **1** are involved and assembled. In particular, the folded parts **3** on one side of the heat transfer plate **1** have another number of folds than the folded parts **3** on the other side of the heat transfer plate **1** resulting in two flow channels **11**, **12** having different heights. In particular, the thin channel **11** has only one fold which directly abuts to the metal sheet, resulting in a flow channel **11** with a height of one times the thickness of the metal sheet **5**. The second folded part on the other side of the plane of the heat transfer wall **2** has two folds and abut to folded parts **3** of another heat transfer plate **2** which is single folded. This assembly results in a flow channel **12** with a height of tree times the thickness of the metal sheet for the first channel **11** and three times the thickness of the metal sheet for the second channel **12**.

[0093] FIG. **11** illustrates another embodiment of the present invention, wherein the same type of heat transfer plates having two adjacent folded parts **3** is used. The folded part on the short side of the heat transfer plate has one fold, generating a spacer having a thickness of one times the thickness of the metal sheet the heat transfer plate is made of, whereas the second, adjacent folded part has three folds, engendering a thickness of the corresponding spacer of three times the thickness of the metal sheet the heat transfer plate is made of. The first plate **101** is arranged to have the one folded part **3** having three folds facing the second heat transfer plate **102**. This second heat transfer plate **102** is arranged having another folded part **3** having three folds facing the first heat transfer plate **101** opposite to the folded part with three folds of the first heat transfer plate **101**. In the assembled state, this pair of heat transfer plates **101**, **102** will form a channel **11**, **12** with a precise height of three times the thickness of the metal sheet **5** as the folded parts with three folds abut directly the circumferential portion **22** of the respective heat transfer plate **1**. On the other side, the second heat transfer plate **102** faces a third heat transfer plate **103**. The second heat transfer plate **102** has a folded part with a single fold adjacent to the folded part with three folds as the folded part directly abuts the circumferential portion **22** of the respective heat transfer plate **1**. This side of the heat transfer plate **102** will abut with the third heat transfer plate **103**. The third heat transfer plate **103** is arranged facing the second heat transfer plate **102** with its single folded part at the opposite side of the heat transfer plate **103**. In the assembled state, this pair of heat transfer plates **102**, **103** will form a second channel with a precise height of once the thickness of the metal sheet as the folded part directly abuts the circumferential portion **22** of the respective heat transfer plate **1**.

[0094] These embodiments show the high versatility of the present invention offering the possibility to flexibly assemble heat transfer plates of one type or different types of heat transfer plates for accommodating to the needs of the plate heat exchanger. The invention is not limited to the embodiments described here. In particular, the plate heat exchanger may have other W to L ratio as long as W is larger than L. The number of folds between each heat transfer walls may also vary, resulting for example in a first channel height of one times the thickness t of the metal sheet and in a second channel height of three of times the thickness t of the

metal sheet. Another example for the total number of folds separating the heat transfer walls may be 1 to 4.

1. Plate heat exchanger for gas-liquid heat exchange comprising a stack of rectangular heat transfer plates,

wherein first and second flow channels are arranged alternately between the heat transfer plates of the stack, with every first flow channel for a through-flow of a first fluid and every second flow channel for a through-flow of a second fluid,

wherein each rectangular heat transfer plate comprises a circumference with four circumference edges arranged at the circumference of the rectangular heat transfer plate, a rectangular heat transfer wall extending between the circumference edges of the heat transfer plate, the rectangular heat transfer wall defining a plane and comprising a circumference portion extending to the circumference edge in the plane of the heat transfer wall, and the heat transfer plate further comprises at least two folded parts arranged at the circumference of the heat transfer plate and extending from the heat transfer wall over the circumference edge of the heat transfer plate, the folded parts contacting the heat transfer wall for forming spacer elements,

wherein two opposite folded parts are folded from the heat transfer wall towards a same side of the plane of the rectangular heat transfer wall, or at least two adjacent folded parts of the rectangular heat transfer wall are each folded from the heat transfer wall towards opposite sides of the plane of the rectangular heat transfer wall with respect to the adjacent folded part, and wherein pairs of heat transfer plates are arranged so that each folded part of one heat transfer plate is in contact either with a folded part of an adjacent heat transfer plate or with a circumference portion of the heat transfer wall of an adjacent heat transfer plate.

2. Plate heat exchanger according to claim **1**, wherein the circumference edges comprise two length side edges and two width side edges, wherein the plate heat exchanger comprises first inlet and outlet openings formed by corresponding pairs of heat transfer plates and arranged at the length side edge and second inlet and outlet openings formed by corresponding pairs of heat transfer plates and arranged at the width side edge, and wherein a length (W) of each second inlet and outlet opening at the width side edges is larger than a length (L) of each first inlet and outlet opening at the length side edges.

3. Plate heat exchanger according to claim **2**, wherein the length (W) of each second inlet and outlet opening is at least 2 times larger, particularly at least 2.5 times larger, very particularly at least 3 times larger than the length (L) of each first inlet and outlet opening.

4. Plate heat exchanger according to claim **2**, wherein the total number of folds of the folded parts separating the respective heat transfer walls on the width side edges and delimiting the first inlet and outlet openings is larger than the total number of folds of the folded parts separating the respective heat transfer walls on the length side edges and delimiting the second inlet and outlet openings.

5. Plate heat exchanger according to claim **1**, wherein the first flow channels are liquid flow channels extending from the first inlet openings to the first outlet openings and are connectable to a liquid inlet port and a liquid outlet port respectively and forming a liquid channel path, and the second flow channels are gas flow channels extending from the second inlet openings to the second outlet openings and are connectable to a gas inlet port and a gas outlet port and forming a gas channel path.

6. Plate heat exchanger according to claim **4**, wherein the liquid channel path is orthogonal to the gas channel path.

7. Plate heat exchanger according to claim **1**, wherein at least one folded part has two or more folds folded onto each other.

8. Plate heat exchanger according to claim **1**, wherein at least three folded parts of the rectangular heat transfer wall are each folded from the heat transfer wall, in an alternating sequence, towards opposite sides of the plane of the rectangular heat transfer wall so that adjacent pairs folded parts are folded towards opposite sides of the plane of the rectangular heat transfer wall.

9. Plate heat exchanger according to claim **1**, wherein the heat transfer plates are made of a metal sheet having a thickness t and having a shape adapted to form the heat transfer plate.

10. Plate heat exchanger according to claim **1**, wherein the folded parts have a thickness corresponding to the number of folds of the folded part times the thickness t of the metal sheet.

11. Plate heat exchanger according to claim **1**, wherein the heat transfer walls are separated by the folded parts by a distance corresponding to the number of folds of the respective folded parts separating the corresponding heat transfer walls times the thickness t of the metal sheet the heat transfer plate is made of.

12. Plate heat exchanger according to claim **1**, wherein the heat transfer walls comprise a three-dimensional structure such as corrugations, dimples or chevrons.

13. Plate heat exchanger according to claim **1**, wherein the heat transfer plates are stacked against each other and joined together by welding, brazing or fusion bonding at least on the width side of the heat transfer plates.

14. Plate heat exchanger according to claim **1**, wherein the plate heat exchanger comprises at least one end plate for sealing the plate heat exchanger.

15. Plate heat exchanger according to claim **1**, wherein the thickness of the metal sheet the heat transfer plate is made of is in the range of from 0.5 mm to 2 mm, particularly from 0.7 mm to 1.3 mm very in particular from 0.75 mm to 1.25 mm.

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