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(54) **Plate heat exchanger with mounting flange**

(57) A plate heat exchanger (1) comprises a plate package (2) of permanently connected heat exchanger plates that defines a surrounding wall (4). Two mounting plates (7) are permanently connected to an end surface (5) of the plate package (2), in spaced relation to each other. Each mounting plate (7) comprises opposing flat engagement surfaces connected by an edge portion that extends along the perimeter of the mounting plate (7). Each mounting plate (7) is arranged with one of its engagement surfaces permanently connected to the end

surface (5), such that the perimeter of the mounting plate (7) partially extends beyond the surrounding wall (4), to define a mounting flange, and partially extends across the end surface (5) in contact with the same within the perimeter of the surrounding wall (4). The perimeter of the mounting plate (7) defines a concave shape comprising two concave portions (15) as seen in a normal direction to the end surface (5), the concave portions (15) being located to intersect the surrounding external wall (4).

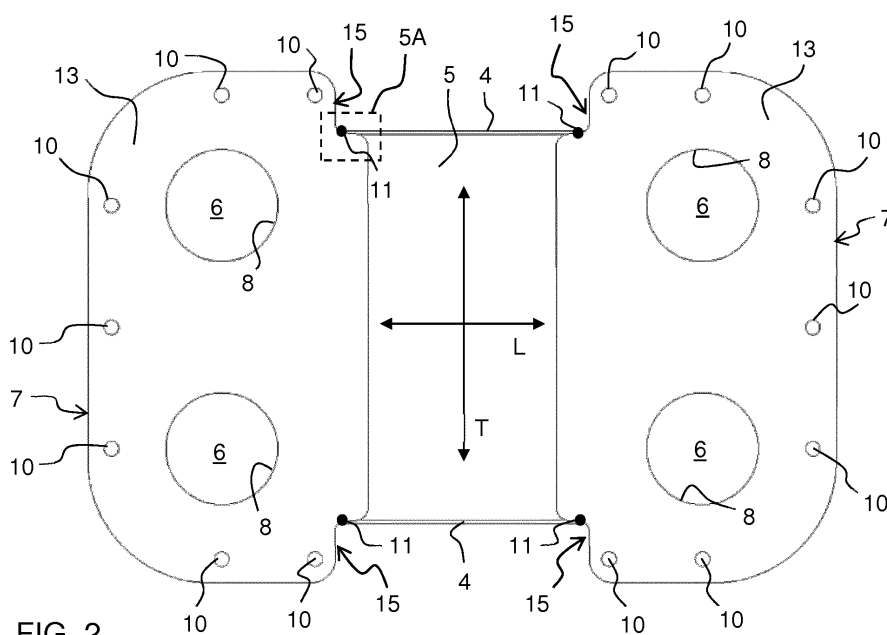


FIG. 2

Description

Technical Field

[0001] The present invention relates to a plate heat exchanger that comprises a plurality of heat exchanger plates which are stacked and permanently connected to form a plate package and a mounting structure which is permanently connected to the plate package for releasable attachment of the plate heat exchanger to an external supporting structure.

Background

[0002] Heat exchangers are utilized in various technical applications for transferring heat from one fluid to another fluid. Heat exchangers in plate configuration are well-known in the art. In these heat exchangers, a plurality of stacked plates having overlapping peripheral side walls are put together and permanently connected to define a plate package with hollow fluid passages between the plates, usually with different fluids in heat exchange relationship in alternating spaces between the plates. Usually a coherent base plate or mounting plate is directly or indirectly attached to the outermost one of the stacked plates. The mounting plate has an extension that exceeds the stack of plates so as to define a circumferential mounting flange. The mounting flange has holes or fasteners to attach the heat exchanger to a piece of equipment. This type of plate heat exchanger is e.g. known from US2010/0258095 and US8181695.

[0003] When fastened on the piece of equipment, the mounting plate may be subjected to a significant pressure and weight load which tends to deform the mounting plate. To achieve an adequate strength and rigidity, the mounting plate needs to be comparatively thick. Such a thick mounting plate may add significantly to the weight of the heat exchanger. Furthermore, the use of a thick mounting plate leads to a larger consumption of material and a higher cost for the heat exchanger.

[0004] The need for a thick mounting plate may be particularly pronounced when the heat exchanger is mounted in an environment which is subjected to vibrations. Such vibrations may e.g. occur when the plate heat exchanger is mounted in a vehicle such as a car, truck, bus, ship or airplane. In these environments, the design of the plate heat exchanger in general, and the design and attachment of the mounting plate in particular, need to take into account the risk for fatigue failure caused by cyclic loading and unloading of the mounting plate by the vibrations. The cyclic stresses in the heat exchanger may cause it to fail due to fatigue, especially in the joints between the plates, even if the nominal stress values are well below the tensile stress limit. The risk for fatigue failure is typically handled by further increasing the thickness of the mounting plate, which will make it even more difficult to keep down the weight and cost of the plate heat exchanger.

Summary

[0005] It is an objective of the invention to at least partly overcome one or more limitations of the prior art.

[0006] Another objective is to provide a plate heat exchanger with a relatively low weight and a relatively high strength when mounted to an external supporting structure.

[0007] A further objective is to provide a plate heat exchanger that can be manufactured at low cost.

[0008] Yet another objective is to provide a plate heat exchanger suitable for use in environments subjected to vibrations.

[0009] One or more of these objects, as well as further objects that may appear from the description below, are at least partly achieved by a plate heat exchanger according to the independent claim, embodiments thereof being defined by the dependent claims.

[0010] A first aspect of the invention is a plate heat exchanger, comprising: a plurality of heat exchanger plates which are stacked and permanently connected to form a plate package that defines first and second fluid paths for a first medium and a second medium, respectively, separated by said heat exchanger plates, said plate package defining a surrounding external wall that extends in an axial direction between first and second axial ends; an end plate permanently connected to one of the first and second axial ends so as to provide an end surface that extends between first and second longitudinal ends in a lateral plane which is orthogonal to the axial direction; and two mounting plates permanently connected to a respective surface portion of the end surface at the first longitudinal end and the second longitudinal end, respectively, such that the mounting plates are spaced from each other in a longitudinal direction on the end surface, wherein the respective mounting plate comprises opposing flat engagement surfaces connected by an edge portion that extends along the perimeter of the mounting plate. The respective mounting plate is arranged with one of its engagement surfaces permanently connected to the end surface, such that the perimeter of the mounting plate partially extends beyond the surrounding external wall, so as to define a mounting flange, and partially extends across the end surface in contact with the same within the perimeter of the surrounding external wall. The perimeter of the mounting plate defines a concave shape comprising two concave portions as seen in a normal direction to the end surface, the concave portions being located to intersect the surrounding external wall at a respective intersection point.

[0011] The inventive plate heat exchanger is based on the insight that the coherent mounting plate of the prior art may be replaced by two smaller mounting plates that are located at a respective longitudinal end on the end surface on the plate package to provide a respective mounting flange for the heat exchanger. The use of two smaller, separated mounting plates may reduce the weight of the heat exchanger, and also its manufacturing

cost, since material is eliminated in the space between the mounting plates, beneath the end surface of the plate package. The inventive heat exchanger is furthermore based on the insight that the use of two separated mounting plates may lead to local stress concentration in the heat exchanger, which may act to reduce the heat exchanger's ability to sustain loads, and in particular cyclic loads. The concentration of stress has been found to originate in the region where the edge portion of the mounting plate intersects the surrounding wall of the plate package. To counteract stress concentration in a simple and efficient way, the perimeter of the mounting plate is shaped with two concave portions which are located to intersect the surrounding wall at a respective intersection point. An improved distribution of stress is enabled since the concave portions increase the extent of the perimeter of the mounting plate in a region at and around the intersection points and since the concave portions may orient the perimeter of the mounting plate to the surrounding wall so as to distribute stress.

[0012] The distribution of stress may be controlled further by optimizing the design parameters of the heat exchanger in general, and the mounting plates in particular, for example according to the following embodiments.

[0013] In one embodiment, a subset of the respective concave portion is located at or within the surrounding external wall and is non-perpendicular to the perimeter of the surrounding external wall at the respective intersection point, as seen in the normal direction to the end surface. The subset of the respective concave portion may extend from a starting point to an end point on the concave portion, such that the local inclination of the concave portion, given by a tangential line, along said subset is less than a maximum design angle, and the end point may be located where the local inclination exceeds the maximum design angle.

[0014] In one embodiment, the maximum design angle is defined between the tangential line and the longitudinal direction and has a value of approximately 65°.

[0015] In one embodiment, the subset comprises an essentially linear portion within at least 30% of the subset, said linear portion having a predefined angle, to the longitudinal direction, which is less than the maximum design angle.

[0016] In one embodiment, the subset of the respective concave portion has a first extent in the longitudinal direction and a second extent in a transverse direction, which is orthogonal to the longitudinal direction in the plane of the mounting plate, wherein the ratio of the second extent to the first extent is equal to or less than approximately 2, and preferably equal to or less than approximately 1 or approximately 0.5.

[0017] In one embodiment, the predefined starting point of the subset is located within a maximum design distance, in the transverse direction, from the respective intersection point, wherein the maximum design distance is 20% of the first extent.

[0018] In one embodiment, the starting point essentially

ly coincides with the respective intersection point.

[0019] In one embodiment, the end point is located on an outward corner of the mounting plate, the outward corner being defined by a second radius.

[0020] In one embodiment, the perimeter of the mounting plate is non-perpendicular to the perimeter of the surrounding external wall at the respective intersection point, as seen in the normal direction to the end surface.

[0021] In one embodiment, the mounting plate abuts on and is permanently connected to the end surface along said subset of the concave portion.

[0022] In one embodiment, the respective concave portion comprises an inward corner defined by a first radius, said inward corner intersecting the surrounding external wall at the intersection point, as seen in the direction normal to the end surface.

[0023] In one embodiment, the respective concave portion extends between two limit points on the perimeter of the mounting plate, said limit points being defined by a mathematical line which intersects the perimeter of the mounting plate only at the limit points and which extends beyond the perimeter of the mounting plate intermediate the limit points, as seen in the direction normal to the end surface.

[0024] In one embodiment, the end plate is a sealing plate which is permanently and sealingly connected to one of the heat exchanger plates at one of said first and second axial ends.

[0025] In an alternative embodiment, the end plate is a reinforcement plate which is permanently connected to a sealing plate on the plate package, wherein the end plate has at least two supporting flanges that extend beyond the perimeter of the surrounding external wall so as to abut on the mounting flange defined by the respective mounting plate. Further, the end plate may comprise, along its perimeter and as seen in the normal direction of the end surface, concave or beveled surfaces adjacent to the supporting flanges, wherein the concave or beveled surfaces may be located to overlap the perimeter of the respective mounting plate at the intersection points, and the respective concave or beveled surface may be non-perpendicular to, and preferably co-extending with, the perimeter of the mounting plate at the overlap, as seen in the normal direction to the end surface.

[0026] In one embodiment, at least one of the mounting plates defines at least one through hole that extends between the engagement surfaces and is aligned with a corresponding through hole defined in the end plate and an internal channel defined in the plate package, so as to form an inlet or an outlet for the first or the second medium.

[0027] In one embodiment, the mounting flange comprises a plurality of mounting holes adapted to receive bolts or pins for fastening the plate heat exchanger.

[0028] In one embodiment, the heat exchanger plates are permanently joined to each other through melting of metallic material.

[0029] Still other objectives, features, aspects and ad-

vantages of the present invention will appear from the following detailed description, from the attached claims as well as from the drawings.

Brief Description of Drawings

[0030] Embodiments of the invention will now be described in more detail with reference to the accompanying schematic drawings.

Fig. 1 is a perspective view of a plate heat exchanger according to an embodiment of the invention.

Fig. 2 is a bottom plan view of the plate heat exchanger in Fig. 1.

Figs 3A-3B are perspective views from two directions of a mounting plate included in the plate heat exchanger in Fig. 1.

Fig. 4 is a bottom plan view of the mounting plate in Figs 3A-3B.

Fig. 5A is an enlarged view of a portion in Fig. 2 to illustrate a set of design parameters for the mounting plate included in the plate heat exchanger, Fig. 5B is a view corresponding to Fig. 5A to illustrate design parameters in an alternative configuration, and Figs 5C-5D are perspective views from above and below, respectively, of the portion shown in Fig. 5A.

Fig. 6 is a partial perspective view of a plate heat exchanger with a convex mounting plate.

Fig. 7 is a perspective view of a sealing plate included in the plate heat exchanger of Fig. 1.

Fig. 8 is a perspective view of a reinforcement plate included in the plate heat exchanger of Fig. 1.

Figs 9A-9B are partial plan views of a plate heat exchanger with concave mounting plates of alternative configuration.

Detailed Description of Example Embodiments

[0031] Embodiments of the present invention relate to configurations of a mounting structure on a plate heat exchanger. Corresponding elements are designated by the same reference numerals.

[0032] Figs 1-2 disclose an embodiment of a plate heat exchanger 1 according to the invention. The plate heat exchanger 1 comprises a plurality of plates which are stacked one on top of the other to form a plate package 2. The plate package 2 may be of any conventional design. Generally the plate package 2 comprises a plurality of heat exchanger plates 3 with corrugated heat transfer portions that define flow passages (Internal channels) for a first and second fluid between the heat exchanger plates 3 such that heat is transferred through the heat transfer portions from one fluid to the other. The heat exchanger plates 3 may be single-walled or double-walled. The heat exchanger plates 3 are only schematically indicated in Fig. 1, since they are well-known to the person skilled in the art and their configuration is not essential for the present invention. The plate package 2

has the general shape of a rectangular cuboid, albeit with rounded corners. Other shapes are conceivable. Generally, the plate package 2 defines a surrounding external wall 4 which extends in a height or axial direction A between a top axial end and a bottom axial end. The wall 4 has a given perimeter or contour at its bottom axial end. In the illustrated example, the wall 4 has essentially the same contour along its extent in the axial direction A. The bottom axial end of the plate package 2 comprises or is provided with an essentially planar end surface 5 (Fig. 2), which may but need not conform to the contour of the wall 4 at the bottom axial end. The end surface 5 extends in a lateral plane. Generally, the plate package 2, and the end surface 5, extends between two longitudinal ends in a longitudinal direction L and between two transverse ends in a transverse direction T (Fig. 2).

[0033] Although not shown on the drawings, the heat transfer plates 3 have in their corner portions through-openings, which form inlet channels and outlet channels in communication with the flow passages for the first fluid and the second fluid. These inlet and outlet channels open in the end surface 5 of the plate package 2 to define separate portholes for inlet and outlet of the first and second fluids, respectively. In the illustrated example, the end surface 5 has four portholes 6 (Fig. 2).

[0034] The plate package 2 is permanently connected to two identical (in this example) mounting plates 7, which are arranged on a respective end portion of the end surface 5. The mounting plates 7 are thereby separated in the longitudinal direction L, leaving a space free of material beneath the center portion of the plate package 2. Compared to using a single mounting plate that extends beneath the entire plate package 2, the illustrated configuration saves weight and material of the heat exchanger 1, and thereby also cost. Each mounting plate 7 has two through-holes 8 which are mated with a respective pair of the portholes 6 of the plate package 2 to define inlet and outlet ports of the heat exchanger 1. The mounting plates 7 are configured for attaching the heat exchanger 1 to an external suspension structure (not shown) such that the inlet and outlet ports mate with corresponding supply ports for the first and second medium on the external structure. Optionally, one or more seals (not shown) may be provided in the interface between the mounting plate 7 and the external structure.

[0035] Each mounting plate 7 defines a mounting flange 9 that projects from the wall 4 and extends around the longitudinal end of the plate package 2. Bores 10 are provided in the mounting flange 9 as a means for fastening the heat exchanger 1 to the external structure. Threaded fasteners or bolts, for example, may be introduced into the bores 10 for engagement with corresponding bores in the external structure.

[0036] The plate package 2 and the mounting plates 7 are made of metal, such as stainless steel or aluminum. All the plates in the heat exchanger 1 are permanently connected to each other, preferably through melting of a metallic material, such as brazing, welding or a combi-

nation of brazing and welding. The plates in the plate package 2 may alternatively be permanently connected by gluing.

[0037] The mounting plates 7 are dimensioned, with respect to material, thickness and extent in the longitudinal and transverse directions, so as to have an adequate strength and stiffness to the static load that is applied to the mounting plates 7 when fastened on the external structure. The static load, which tends to deform the mounting plates 7, may originate from a combination of the weight of the heat exchanger 1, internal pressure applied by the media in the heat exchanger 1 and transferred to the mounting plates 7, and compression forces applied to the mounting plates 7, e.g. at the above-mentioned seals, via the fasteners and the bores 10. This static load tend to deform the mounting plates 7. As seen in Figs 1-3, the mounting plates 7 are generally designed to have a significant thickness. As a non-limiting example, the thickness may be 15-40 mm. The bottom of the plate package 2, on the other hand, is normally made of much thinner material.

[0038] If the heat exchanger 1 is installed in an environment where vibrations are transferred to the mounting plate 7 via the external structure, the heat exchanger 1 also needs to be designed to account for the mechanical stresses caused by the cyclic loading of the vibrations, i.e. cyclic stresses. For example, such vibrations occur for heat exchangers that are mounted in vehicles, such as cars, trucks and ships. In one non-limiting example, the heat exchanger 1 is an oil cooler for an engine. When cyclic stresses are applied to a material, even though the stresses do not cause plastic deformation, the material may fail due to fatigue especially in local regions with high stress concentration. The use of stiff thick mounting plates 7 connected to a plate package 2 with a relatively thin bottom is likely to lead to high concentrations of cyclic stress at the interface between the mounting plates 7 and the plate package 2, and possibly also within the plate package 2.

[0039] Embodiments of the present invention are designed to counteract stress concentration that may lead to fatigue failure. To this end, the mounting plates 7 have a perimeter with concave portions 15, which are located so as to intersect the perimeter of the surrounding wall 4 of the plate package 2, as seen in the normal direction to the end surface 5. As used herein, the "perimeter" designates the outer contour as seen in plan view. In the plan view of Fig. 2, intersection points 11 between the perimeters of the mounting plates 7 and the wall 4 are indicated by black dots. By providing the concave portions 15 at the intersection points 11, the perimeter of the mounting plate 7 is given an increased extent in a region at and around the intersection points 11. The increased extent favors distribution of stress. Furthermore, the concave portions 15 generally define more favorable angles between the perimeter of the mounting plate 7 and the surrounding wall 4 for counteracting stress concentration.

[0040] Figs 3A-3B illustrate a mounting plate 7 in more detail. The mounting plate 7 has essentially planar top and bottom surfaces 12, 13, where the top surface 12 forms an engagement surface to be permanently connected to the end surface 5 on the plate package 2, and the bottom surface 13 forms an engagement surface to be applied and fixed to the external supporting structure. The through-holes 8 and bores 10 are formed to extend between the top and bottom surfaces 12, 13. At the perimeter of the mounting plate 7, the top and bottom surfaces are connected by a peripheral edge surface 14. The edge surface 14 is essentially planar and right-angled to the top and bottom surfaces 12, 13 and defines the perimeter of the mounting plate 7.

[0041] The mounting plate 7 is generally elongated and has a concave shape, as seen in plan view. The term "concave shape" is used in its ordinary meaning to denote a shape that contains at least one portion that bends inwards, i.e. a concave portion. A concave shape is also known as a "non-convex shape". In a geometric sense, as shown in Fig. 4, each of the concave portions 15 extends between two well-defined limit points C1, C2. The limit points C1, C2 are located where a straight mathematical (fictitious) line ML touches the perimeter of the mounting plate 7 so as to bridge the concave portion 15. The respective line ML thus intersects the perimeter of the mounting plate 7 at only two locations (at C1 and C2) and is spaced from the perimeter of the mounting plate 7 between these two locations. As seen in Fig. 4, the respective concave portion 15 extends to an inward corner between a distal outward corner, containing the limit point C1, and a proximate outward corner, containing the limit point C2.

[0042] In plan view, the concave portions 15 of the mounting plate 7 are connected by an essentially straight contour line that extends across the end surface 5. This design is selected to minimize the width of the mounting plates 7 in the longitudinal direction L (Fig. 2). Other designs are conceivable.

[0043] Fig. 5A is taken within the dashed rectangle 5A in the bottom plan view of Fig. 2 and illustrates a region of overlap between the perimeter of the mounting plate 7 and the plate package 2 near the surrounding wall 4. The wall 4 is hidden from view by intermediate structures (see below), but its location is indicated by a dashed line. In the illustrated example, the inward corner follows an arc of a circle with radius R1. Similarly, the proximate outward corner, which is located on and attached to the end surface 5, follows an arc of a circle with radius R2. In the illustrated example, the inward corner and the proximate outward corner are connected by an essentially straight (linear) line portion.

[0044] Simulations indicate that a more uniform distribution of stress is favored by constraining the angles between the concave portion 15 and the surrounding wall 4 where the concave portion 15 overlaps the plate package, i.e. at and within the perimeter of the surrounding wall 4. The present Applicant has identified a constraint

that may be applied to a subset of the concave portion 15 that overlaps the plate package. This subset is denoted "constrained perimeter" in the following. In the example of Fig. 5A, the constrained perimeter extends from a starting point P1, which coincides with the intersection point 11, to a well-defined end point P2. Along the extent of the constrained perimeter, the local inclination of the perimeter is constrained to be within a predefined angular range. The local inclination is given by the tangent to the perimeter at each individual location on the perimeter, as seen in a normal direction to the end surface 5. The angular range is given by a maximum design angle $\alpha_{\max}$, which is defined with respect to the longitudinal direction L (i.e. the direction of the nearby wall 4). The angular range thus extends from $-\alpha_{\max}$ to $\alpha_{\max}$. The end point P2 is given by the location along the perimeter where the local inclination exceeds the maximum design angle $\alpha_{\max}$, as indicated in Fig. 5A. The constrained perimeter has an overall extent ΔL in the longitudinal direction L and an overall extent ΔT in the transverse direction T. The present Applicant has found that a favorable distribution of stress is achieved by designing the concave portion 15 with a constrained perimeter such that $\Delta T/\Delta L \leq 2$. For example, it may be desirable to configure the concave portion 15 with $\Delta T/\Delta L \leq 1.5$, $\Delta T/\Delta L \leq 1$ or $\Delta T/\Delta L \leq 0.5$.

[0045] Although not clearly shown in Fig. 5A, the mounting plate 7 abuts on and is attached to the end surface 5 along the entire extent of the constrained perimeter. This configuration may improve the stability and durability of the heat exchanger.

[0046] It is currently believed that a favorable distribution of stress is achieved with the maximum design angle $\alpha_{\max}$ set to a value of about 65° , although other values are conceivable. It should also be noted that the maximum design angle $\alpha_{\max}$ generally defines the end point P2, and that the local inclination may be significantly smaller than $\alpha_{\max}$ along a significant portion of the constrained perimeter. Such an example is seen in Fig. 5A. Thus, a further design criterion may be applied to restrict the local inclination to a main angle α_{main} for at least 30%, and typically at least 50%, of the constrained perimeter. For example, the main angle α_{main} may set the inclination of the linear portion that connects circular arcs (defined by R1, R2 in Fig. 5A). The main angle α_{main} is smaller than the maximum design angle $\alpha_{\max}$ and may e.g. be set to approximately 55° , 45° , 35° , 25° , 15° or 5° . The main angle α_{main} may even be 0, which means that the constrained perimeter would partially extend in alignment with the wall 4, i.e. along the dashed line 4 in Fig. 5A.

[0047] It is realized that the radii R1, R2 of the circular arcs, as well as the extent of the line portion (if present) that connects the circular arcs, may be set so as to fulfill the above-described design criteria. It should also be noted that even if an implementation with circular arcs and an essentially linear portion that connects the circular arcs (as in Figs 5A-5B) may simplify manufacture of the mounting plates 7, other configurations of the inward and

outward corners are conceivable.

[0048] It is currently believed that the stress distribution is favored by locating the starting point P1 of the constrained perimeter at the intersection point 11, as shown in Fig. 5A. However, this means that the local inclination of the perimeter at the intersection point 11 should not exceed the maximum design angle $\alpha_{\max}$. However, it is conceivable that other design considerations call for a greater freedom to locate the constrained perimeter. Simulations indicate that a comparable stress distribution is achieved even if the starting point P1 is shifted from the intersection point 11. Fig. 5B illustrates an example of a concave portion 15 that extends across the wall 4 at right angles, whereby the starting point P1 is set to the location where the local inclination equals the maximum design angle $\alpha_{\max}$. This means that the starting point P1 is shifted from the intersection point 11 in both the transverse direction T and the longitudinal direction L. According to one design criterion, the transverse spacing δT between the starting point P1 and the intersection point 11 fulfills $\delta T/\Delta L \leq 0.2$, and preferably $\delta T/\Delta L \leq 0.1$. In a practical implementation, this may correspond to a transverse spacing δT of less than about 5 mm.

[0049] It should be noted, though, that even if it is possible for the concave portion 15 to intersect the wall 4 at right angles, the distribution of stress is generally favored by a non-perpendicular intersection, e.g. as shown in Fig. 5A.

[0050] For reference, it may be noted that the configuration in Fig. 5A is designed with $\alpha_{\text{main}} = 15^\circ$, $\Delta T/\Delta L \leq 4.75/12.21 = 0.39$, $\delta T = 0$, R1 = 10 mm, R2 = 4 mm. The configuration in Fig. 5B is designed with $\alpha_{\text{main}} = 15^\circ$, $\Delta T/\Delta L \leq 8.6/18 = 0.48$, $\delta T/\Delta L = 2/18 = 0.11$, R1 = 1 mm, R2 = 10 mm.

[0051] Figs 5C-5D are perspective views from above and below, respectively, of the juncture between the mounting plate 7 and the plate package 2 for the embodiment in Fig. 5A, where Fig. 5C is taken within the dashed rectangle 5C in Fig. 1. In this particular example, further structures are located in the interface between the plate package and the mounting plate 7, for the purpose of improving the stability and durability of the heat exchanger 1. These structures include a sealing plate 21 which is connected to the stack of heat exchanger plates 3 to define a bottom surface of the plate package 2. The sealing plate 21, as shown in Fig. 7, is generally planar and has through-holes 22 at its corners to be mated with corresponding through-holes in the heat exchanger plates 3. The perimeter of the sealing plate 21 is bent upwards to form a surrounding flange 23 which adapted to abut on and be fixed to a corresponding flange of an overlying heat exchanger plate, as is known in the art. The material thickness of the sealing plate 21 typically exceeds the material thickness of the heat exchanger plates, and thus the surrounding flange 23 may project slightly beyond the perimeter of the surrounding wall 4 (by 1-2 mm). This is illustrated in the bottom plan views of Figs 5A-5B. In certain embodiments, the mounting plates 7 may be di-

rectly attached to the sealing plate 21. In such embodiments, the sealing plate 21 is an end plate that defines the end surface 5.

[0052] However, in the illustrated embodiment, an additional plate 24 is attached intermediate the sealing plate 21 and the mounting plate 7 for the purpose of reinforcing the bottom surface of the plate package 2. Thus, the end surface 5 is defined by this additional reinforcement or supporting plate 24. The use of such a reinforcement plate 24 may be advantageous when the working pressure of one or both of the media conveyed through the heat exchanger 1 is high or when the working pressure for one or both of the media varies over time. The reinforcement plate 24, which is shown in greater detail in Fig. 8, has a uniform thickness and defines through-holes 25 which are matched to the portholes in the plate package 2. The perimeter of the reinforcement plate 24 may be essentially level with the perimeter of the sealing plate 21 or the perimeter of the wall 4 of the plate package 2. However, in the illustrated example, the reinforcement plate 24 is adapted to locally project from the perimeter of the wall 4. Specifically, the reinforcement plate 24 is provided with cutouts 26 that are located to extend in the longitudinal direction between the intersection points 11 on a respective transverse side of the plate package 2 so as to be essentially level with the axial wall 4. In Figs 5A-5B, however, the cutouts 26 are slightly displaced inwardly from the axial wall 4. The longitudinal end points of the cutouts 26 define a respective transition 27 to a projecting tab portion 28. In the example of Figs 5C-5D, the transitions 27 are located to overlap the perimeter of the mounting plate 7 in proximity to the intersection points 11 and are shaped to be non-perpendicular to the perimeter of the mounting plate 7 at the overlap, as seen in a direction towards the bottom of the heat exchanger 1. This configuration of the reinforcement plate 24 will locally decrease the stress in the reinforcement plate 24 at the intersection points 11. The transitions 27 may e.g. form a bevel or a curve from the cutout 26 to the tab 28. In Figs 5C-5D, the transitions 27 are further configured to essentially co-extend with perimeter of the mounting plate 7 at the overlap. Further, as seen in Figs 5C-5D, the tab portions 28 protrude from the plate package 2 to essentially co-extend with and abut against a respective mounting plate 7. This has been found to result in a favorable distribution of stress between the mounting plate 7, the reinforcement plate 24 and the sealing plate 21 especially at the corners of the plate package 2. It will also increase the strength of the joint between the reinforcement plate 24 and the mounting plate 7 due to the increased contact area between them. In an alternative implementation, not shown, the reinforcement plate 24 projects from the plate package 2 around its entire perimeter except for small notches that are located in the proximity of the intersection points 11 to provide transitions 27 that are appropriately shaped to be non-perpendicular to, and preferably co-extending with, the perimeter of the mounting plate 7.

[0053] The design of the mounting plate 7, and the reinforcement plate 24 if present, may be optimized based on the general principles outlined above, by simulating the distribution of stress in the heat exchanger structure. Such simulations may serve to adapt one or more of the thickness of the mounting plates 7, the width of the mounting plate 7 in the longitudinal direction L, the shape and location of the concave portions 15, as well as further design parameters for the concave portions 15, such as the extents ΔL , ΔT (for a given $\alpha_{\max}$), the transverse spacing δT , the radii R1, R2, and the main angle α_{main} . The simulations may be based on any known technique for numerical approximation of stress, such as the finite element method, the finite difference method, and the boundary element method.

[0054] A few non-limiting examples of alternative configurations of the concave portion 15 is shown in Figs 9A-9B. The configuration in Fig. 9A is designed with $\alpha_{\text{main}} = 6^\circ$, $\Delta T/\Delta L \leq 10.4/29.6 = 0.35$, $\delta T = 0$, R1 = 10 mm, R2 = 15 mm. The configuration in Fig. 9B is designed with $\alpha_{\text{main}} = 60^\circ$, $\Delta T/\Delta L \leq 1.7$, $\delta T = 0$, R1 = 10 mm, R2 = 15 mm.

[0055] A simulation of the stress distribution within the structure in Figs 5C-5D, for one specific vibration load condition, indicates that stresses are well-distributed without any significant peaks in the interface between the reinforcement plate 24 and the sealing plate 21. For this particular simulation, the maximum stress levels are distributed along arrow L1, which is co-located with the starting point P1 (Fig. 5A). Here, the stress values are approximately 80 N/mm² (MPa). The simulation also indicates that stresses are equally well-distributed in the interface between the mounting plate 7 and the reinforcement plate 24, where maximum stress levels of approximately 50 N/mm² are distributed along arrow L2 in Fig. 5D. Incidentally, the arrow L2 is co-located with the end point P2. Corresponding simulations for the structure in Fig. 9A indicates corresponding maximum stress levels with a similar distribution. Simulations for the structure in Fig. 9B indicate maximum stress levels of approximately 110 N/mm² around the starting point P1 and approximately 60 N/mm² around the end point P2. For comparison, the stress distribution has also been simulated, for the same vibration load condition, within a heat exchanger provided with a convex mounting plate 7, i.e. a mounting plate 7 without concave portions, as shown in Fig. 6. In this example, the reinforcement plate 24 has the same extension as the sealing plate 21. The simulation indicated a significant stress concentration at the juncture of the mounting plate 7 and the reinforcement plate 24, with a maximum stress value of about 310 N/mm² in region L3.

[0056] It should be understood that the design of the mounting plates 7 is subject to several design considerations. For example, the width of the mounting plates 7 in the longitudinal direction L may be set to minimize weight and/or cost of the heat exchanger. Such a constraint may also limit the available width W of the concave portion 15 in the longitudinal direction L. The width W is

generally indicated in Figs 9A-9B. In principle, the width W should be as long as possible so as to distribute stress over a longer perimeter. As noted, the width W is typically limited in practice. The above-described design criteria stipulate that $\Delta T/\Delta L \leq 2$ for effective suppression of stress concentration. This does not necessarily mean that it is optimal to minimize $\Delta T/\Delta L$. Instead, the design parameters, and thus $\Delta T/\Delta L$, may be optimized to minimize the maximum stress values for any given width W. The structures in Figs 9A-9B have been optimized in this way. Thus, the maximum stress values are minimized at $\Delta T/\Delta L \leq 0.35$ for the structure in Fig. 9A, and at $\Delta T/\Delta L \leq 1.7$ for the structure in Fig. 9B. Generally, the optimum $\Delta T/\Delta L \leq$ increases with decreasing width W. This can be understood by considering that although the stresses at the starting point P1 will decrease with increasing width W and with decreasing ΔT (i.e. as the constricted perimeter is being more parallel to the longitudinal direction L), significant stresses are formed at and around the end point P2 if located close to the surrounding wall 4, when the width W is limited. Thus, the possible optimization with respect to $\Delta T/\Delta L \leq$ is aimed at balancing the stresses formed at the starting point P1 and the stresses formed at the end point P2. Generally, with decreasing width W, the optimum is found by moving the end point P2 away from the wall 4, i.e. by increasing ΔT , e.g. by increasing the main angle α_{main} and/or the radius R2. The foregoing discussion is only given to explain the relevance of the ratio $\Delta T/\Delta L \leq$ and does not imply that the design parameters of the concave portion 15 need to be optimized for a specific width W.

[0057] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and the scope of the appended claims.

[0058] For example, the edge surface 14 may have any shape and angle to the top and bottom surfaces 12, 13 of the mounting plate 7.

[0059] The reinforcement plate 24, as described and exemplified herein, may also be installed in a plate heat exchanger 1 with convex mounting plates 7, e.g. as shown in Fig. 6, to increase the stability and durability of the plate heat exchanger 1 and, to a certain degree, counteract stress concentration at the intersection points 11. Such a reinforcement plate 24 may provide supporting flanges 28 that extend beyond the perimeter of the surrounding wall 4 and are permanently connected to the top surface 12 of the mounting plates 7. The reinforcement plate 24 may also define the above-described transitions 27, which are located to overlap the perimeter of the respective mounting plate 7 at the intersection points 11 and are shaped to be non-perpendicular to, and preferably co-extending with, the perimeter of the respective mounting plate 7 at the overlap.

[0060] As used herein, "top", "bottom", "vertical", "horizontal", etc merely refer to directions in the drawings and does not imply any particular positioning of the heat exchanger 1. Nor does this terminology imply that the mounting plates 7 need to be arranged on any particular end of the plate package 2. Reverting to Fig. 1, the mounting plates may alternatively be arranged on the top axial end of the plate package 2 and may be permanently connected either to a sealing plate or to a reinforcement plate overlying the sealing plate. Furthermore, the mounting plates 7 may be arranged on an end of the plate package 2 that lacks portholes or on which each or at least one porthole 6 is located intermediate the mounting plates 7.

Claims

1. A plate heat exchanger, comprising:

a plurality of heat exchanger plates (3) which are stacked and permanently connected to form a plate package (2) that defines first and second fluid paths for a first medium and a second medium, respectively, separated by said heat exchanger plates (3), said plate package (2) defining a surrounding external wall (4) that extends in an axial direction (A) between first and second axial ends, an end plate (21; 24) permanently connected to one of the first and second axial ends so as to provide an end surface (5) that extends between first and second longitudinal ends in a lateral plane which is orthogonal to the axial direction (A), and two mounting plates (7) permanently connected to a respective surface portion of the end surface (5) at the first longitudinal end and the second longitudinal end, respectively, such that the mounting plates (7) are spaced from each other in a longitudinal direction (L) on the end surface (5), wherein the respective mounting plate (7) comprises opposing flat engagement surfaces (12, 13) connected by an edge portion that extends along the perimeter of the mounting plate (7), wherein the respective mounting plate (7) is arranged with one of its engagement surfaces (12, 13) permanently connected to the end surface (5), such that the perimeter of the mounting plate (7) partially extends beyond the surrounding external wall (4), so as to define a mounting flange (9), and partially extends across the end surface (5) in contact with the same within the perimeter of the surrounding external wall (4), and wherein the perimeter of the mounting plate (7) defines a concave shape comprising two concave portions (15) as seen in a normal direction to the end surface (5), the concave portions (15)

- being located to intersect the surrounding external wall (4) at a respective intersection point (11).
2. The plate heat exchanger of claim 1, wherein a subset of the respective concave portion (15) is located at or within the surrounding external wall (4) and is non-perpendicular to the perimeter of the surrounding external wall (4) at the respective intersection point (11), as seen in the normal direction to the end surface (5).
 3. The plate heat exchanger of claim 2, wherein said subset of the respective concave portion (15) extends from a starting point (P1) to an end point (P2) on the concave portion (15), such that the local inclination of the concave portion, given by a tangential line, along said subset is less than a maximum design angle ($\alpha_{\max}$), and wherein the end point (P2) is located where the local inclination exceeds the maximum design angle ($\alpha_{\max}$).
 4. The plate heat exchanger of claim 3, wherein the maximum design angle is defined between the tangential line and the longitudinal direction (L) and has a value of approximately 65° .
 5. The plate heat exchanger of claim 3 or 4, wherein said subset comprises an essentially linear portion within at least 30% of said subset, said linear portion having a predefined angle (α_{main}), to the longitudinal direction (L), which is less than the maximum design angle ($\alpha_{\max}$).
 6. The plate heat exchanger of any one of claims 3-5, wherein said subset of the respective concave portion (15) has a first extent (ΔL) in the longitudinal direction (L) and a second extent (ΔT) in a transverse direction (T), which is orthogonal to the longitudinal direction (L) in the plane of the mounting plate (7), wherein the ratio of the second extent (ΔT) to the first extent (ΔL) is equal to or less than approximately 2, and preferably equal to or less than approximately 1 or approximately 0.5.
 7. The plate heat exchanger of any one of claims 3-6, wherein the predefined starting point (P1) of said subset is located within a maximum design distance (δT), in the transverse direction (T), from the respective intersection point (11), wherein the maximum design distance (δT) is 20% of the first extent (ΔL).
 8. The plate heat exchanger of any one of claims 3-7, wherein the starting point (P1) essentially coincides with the respective intersection point (11).
 9. The plate heat exchanger of any preceding claim, wherein said end point (P2) is located on an outward corner of the mounting plate (7), said outward corner being defined by a second radius (R2).
 10. The plate heat exchanger of any preceding claim, wherein the perimeter of the mounting plate (7) is non-perpendicular to the perimeter of the surrounding external wall (4) at the respective intersection point (11), as seen in the normal direction to the end surface (5).
 11. The plate heat exchanger of any preceding claim, wherein the mounting plate (7) abuts on and is permanently connected to the end surface (5) along said subset of the concave portion (15).
 12. The plate heat exchanger of any preceding claim, wherein the respective concave portion (15) comprises an inward corner defined by a first radius (R1), said inward corner intersecting the surrounding external wall (4) at the intersection point (11), as seen in the direction normal to the end surface (5).
 13. The plate heat exchanger of any preceding claim, wherein the respective concave portion (15) extends between two limit points (C1, C2) on the perimeter of the mounting plate (7), said limit points (C1, C2) being defined by a mathematical line (ML) which intersects the perimeter of the mounting plate (7) only at the limit points (C1, C2) and which extends beyond the perimeter of the mounting plate (7) intermediate the limit points (C1, C2), as seen in the direction normal to the end surface (5).
 14. The plate heat exchanger of any preceding claim, wherein the end plate (21) is a sealing plate which is permanently and sealingly connected to one of the heat exchanger plates (3) at one of said first and second axial ends.
 15. The plate heat exchanger of any one of claims 1-13, wherein the end plate (24) is a reinforcement plate (24) which is permanently connected to a sealing plate (21) on the plate package (2), wherein the end plate (24) has at least two supporting flanges (28) that extend beyond the perimeter of the surrounding external wall (4) so as to abut on the mounting flange (9) defined by the respective mounting plate (7).
 16. The plate heat exchanger of claim 15, wherein the end plate (24) comprises, along its perimeter and as seen in the normal direction of the end surface (5), concave or beveled surfaces (27) adjacent to the supporting flanges (28), wherein the concave or beveled surfaces (27) are located to overlap the perimeter of the respective mounting plate (7) at the intersection points (11), and wherein the respective concave or beveled surface (27) is non-perpendicular to, and preferably co-extending with, the perimeter

of the mounting plate (7) at the overlap, as seen in the normal direction to the end surface (5).

17. The plate heat exchanger of any preceding claim, wherein at least one of the mounting plates (7) defines at least one through hole (8) that extends between the engagement surfaces (12, 13) and is aligned with a corresponding through hole (22; 25) defined in the end plate (21; 24) and an internal channel defined in the plate package (2), so as to form an inlet or an outlet for the first or the second medium.
18. The plate heat exchanger of any preceding claim, wherein the mounting flange (9) comprises a plurality of mounting holes (10) adapted to receive bolts or pins for fastening the plate heat exchanger.
19. The plate heat exchanger of any preceding claim, wherein the heat exchanger plates (3) are permanently joined to each other through melting of metallic material.

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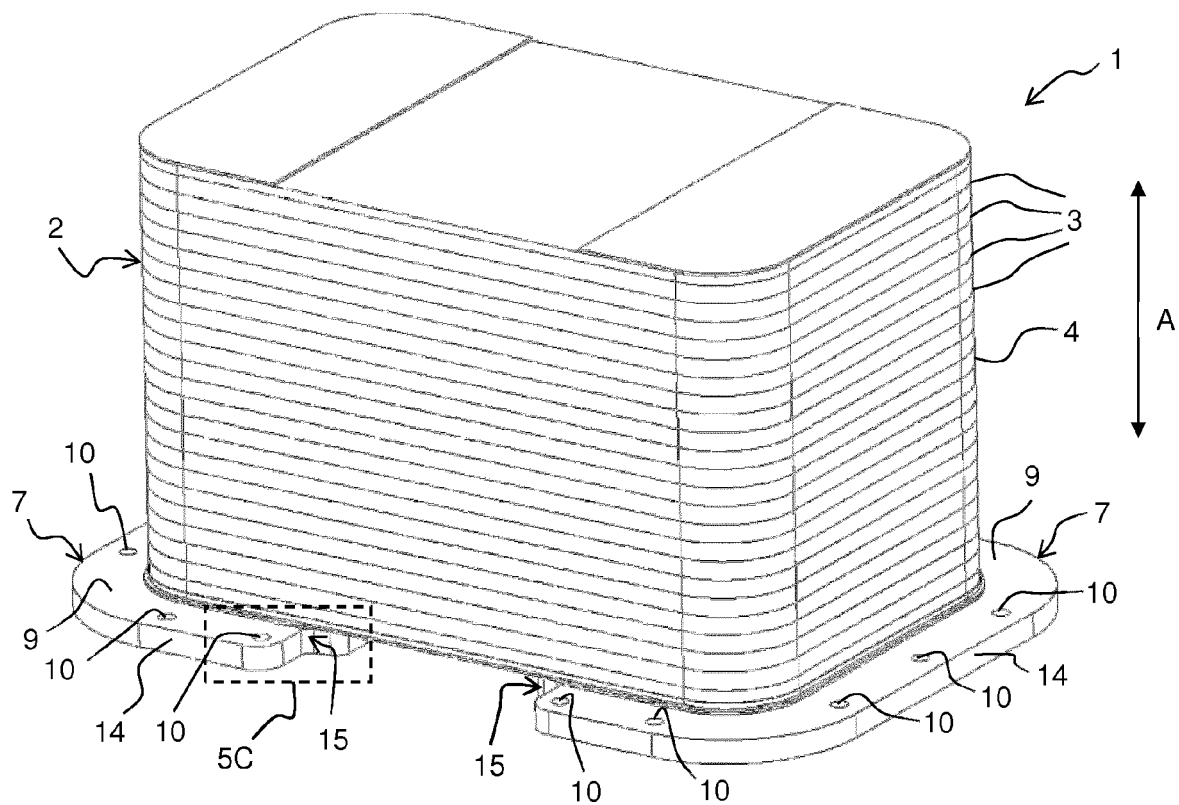


FIG. 1

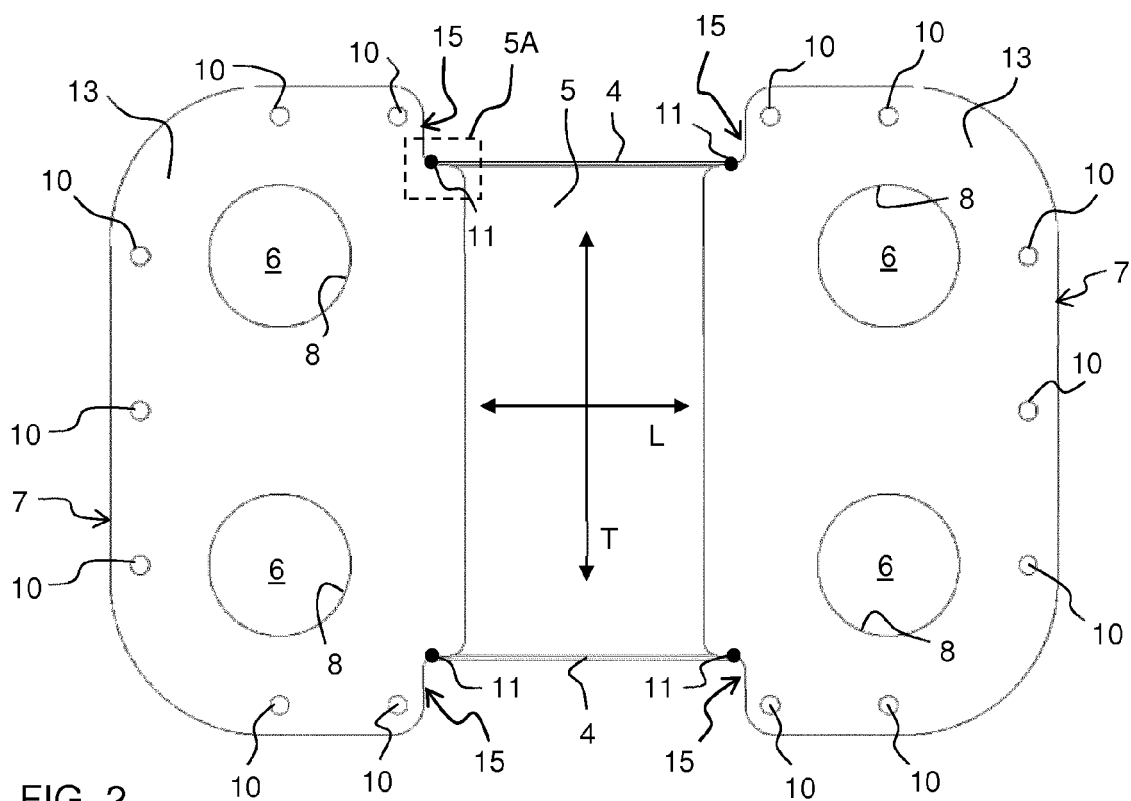


FIG. 2

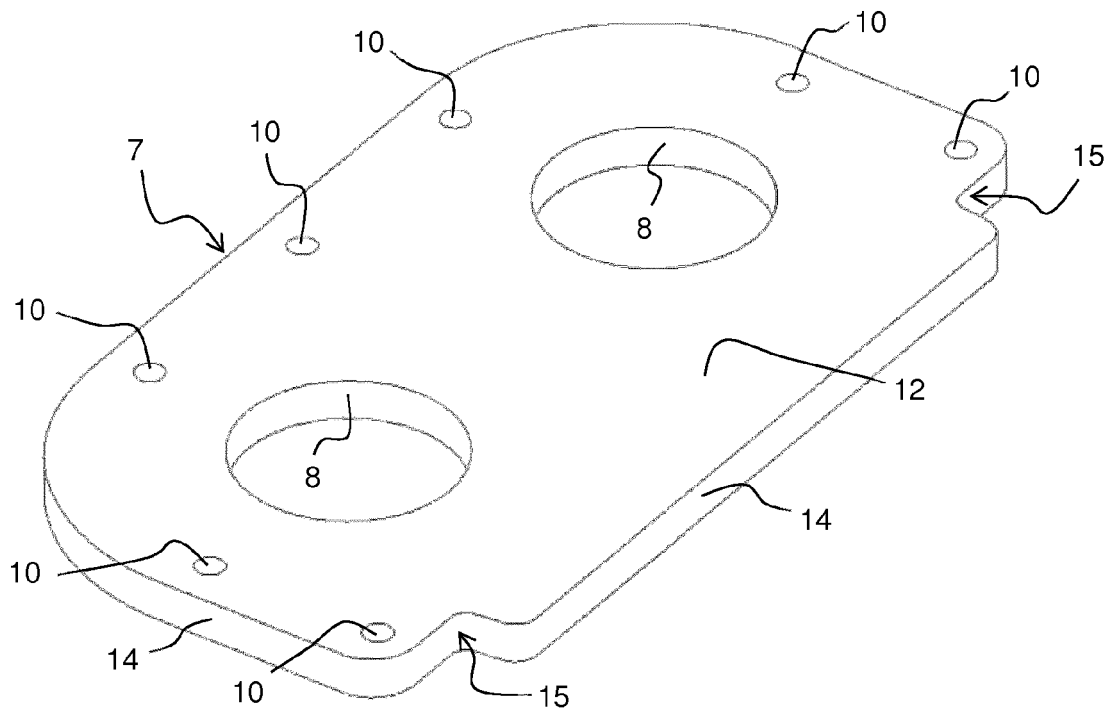


FIG. 3A

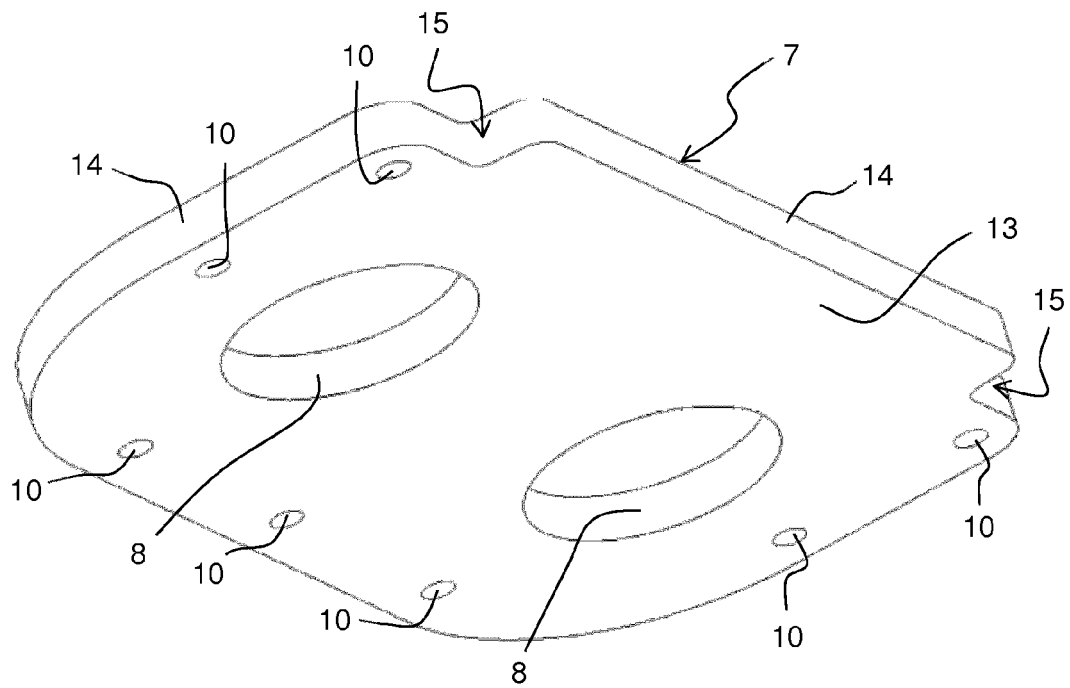


FIG. 3B

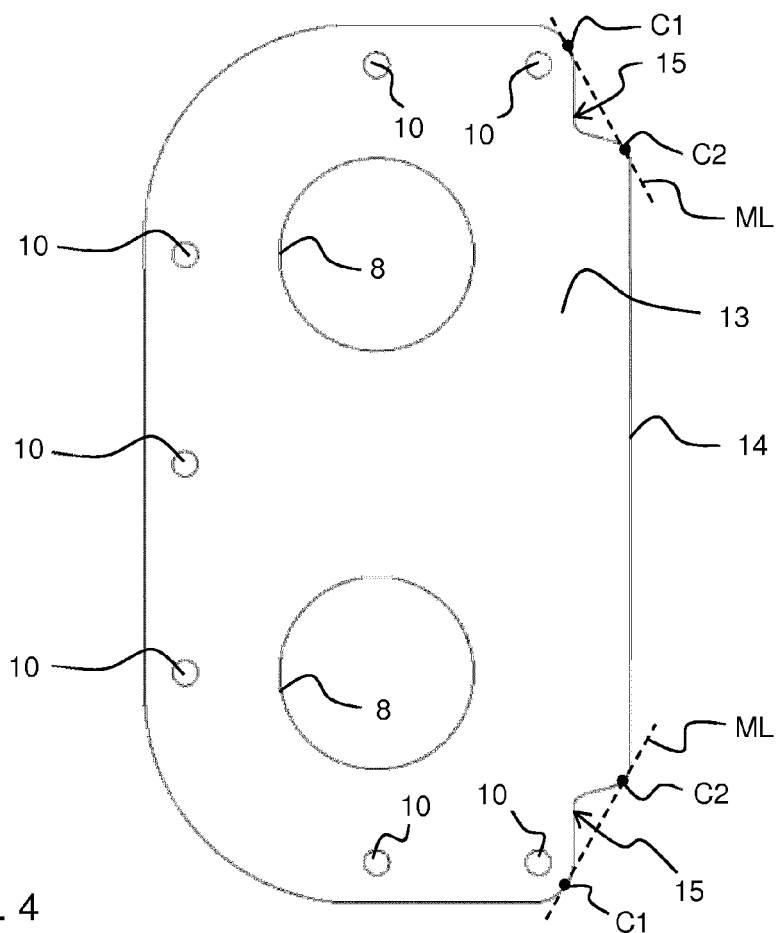


FIG. 4

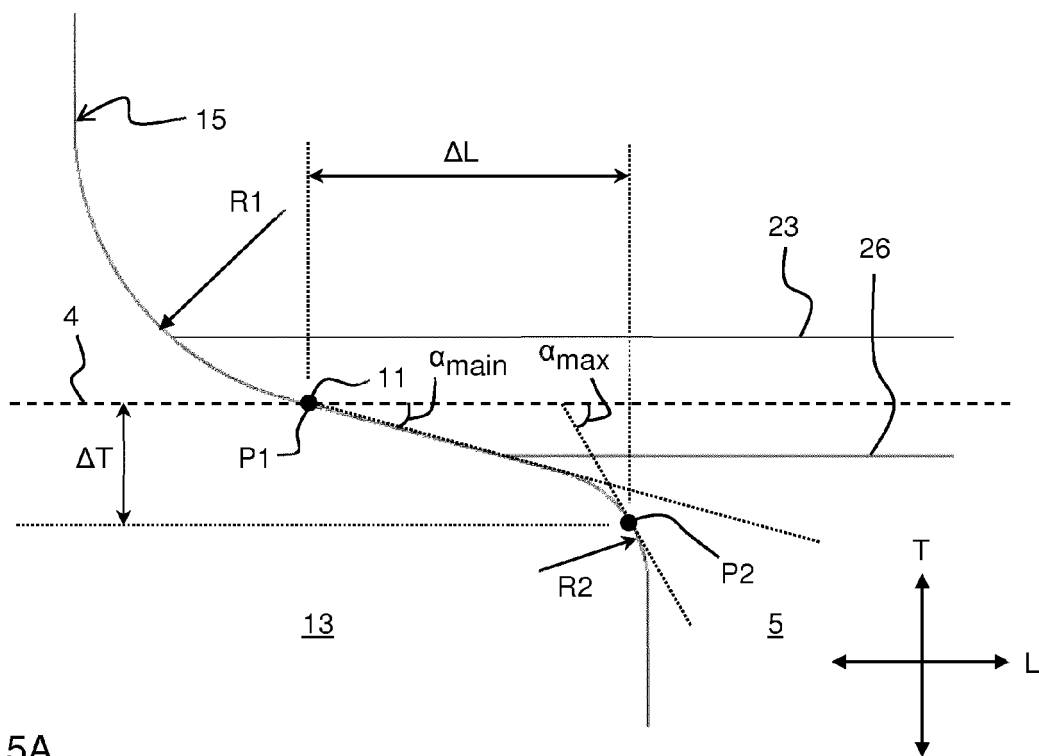


FIG. 5A

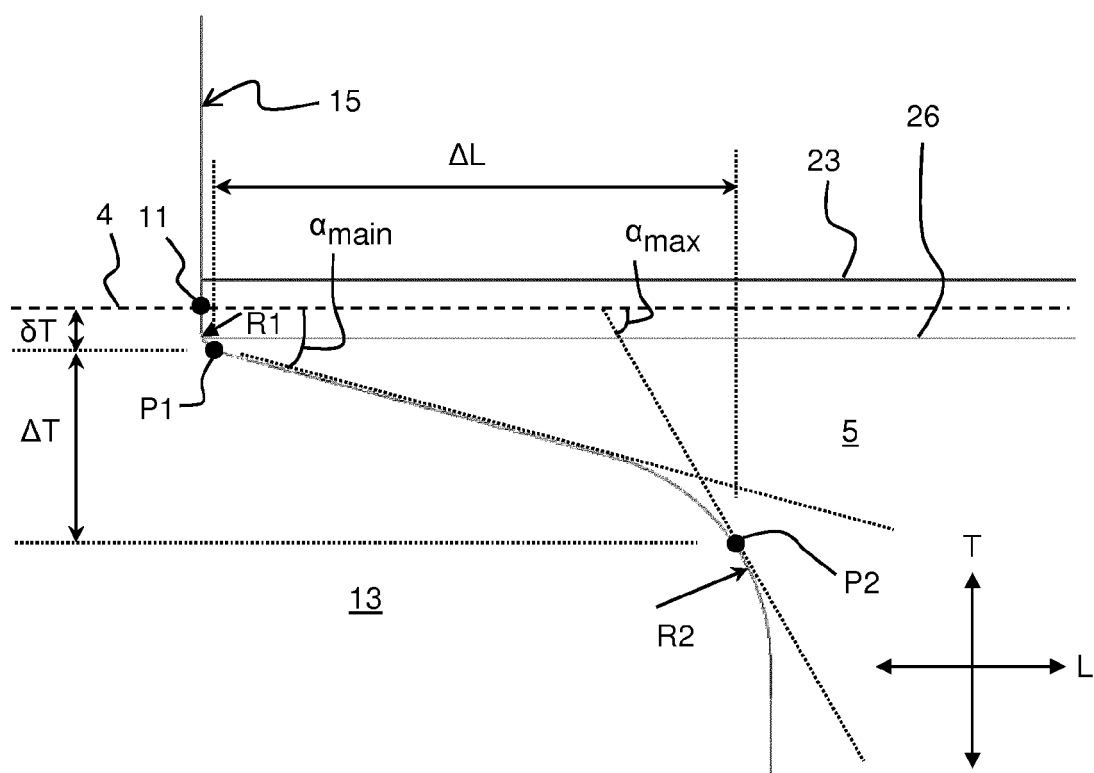


FIG. 5B

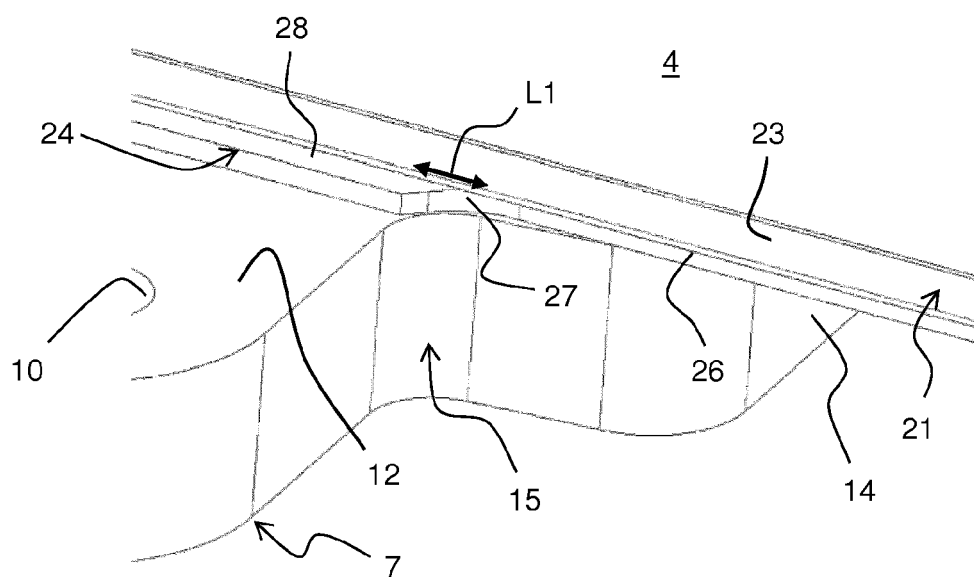


FIG. 5C

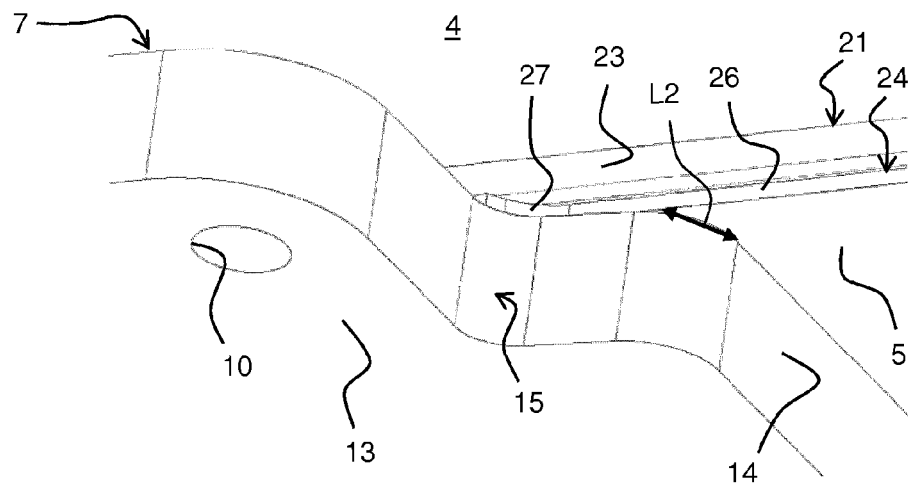


FIG. 5D

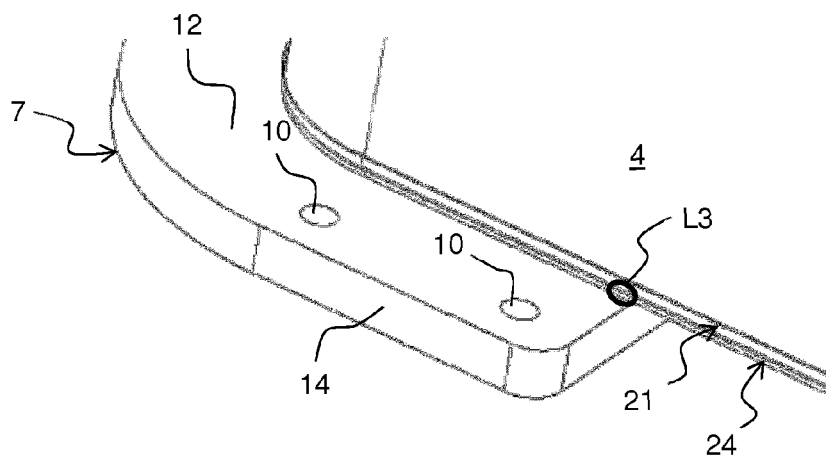


FIG. 6

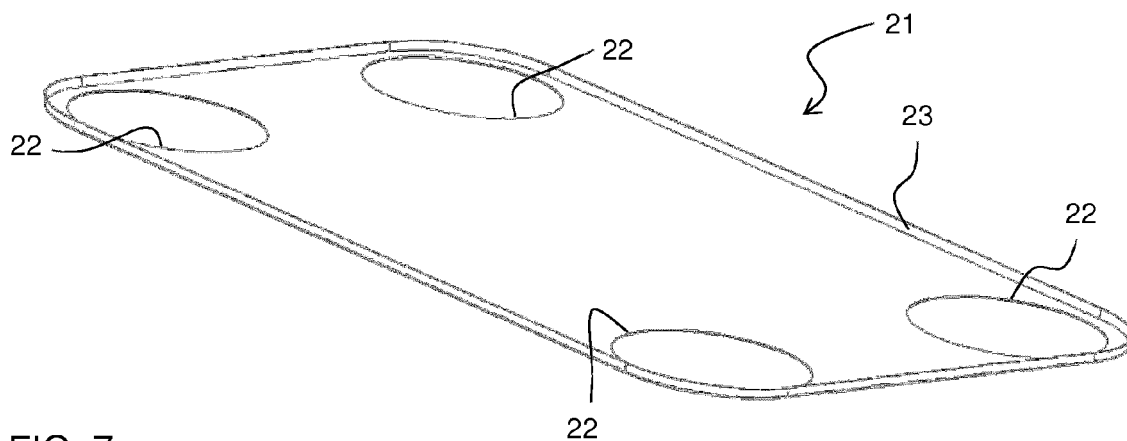


FIG. 7

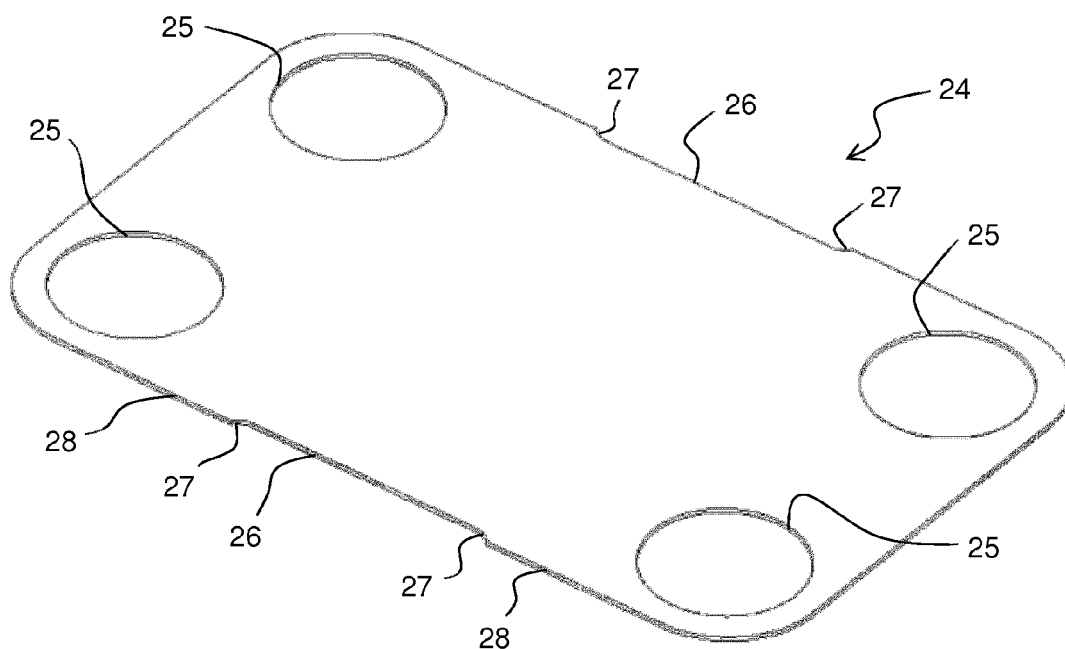


FIG. 8

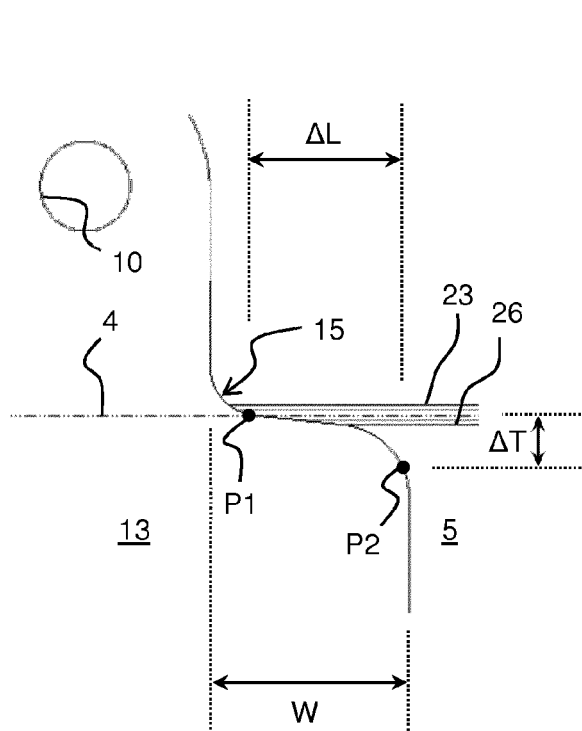


FIG. 9A

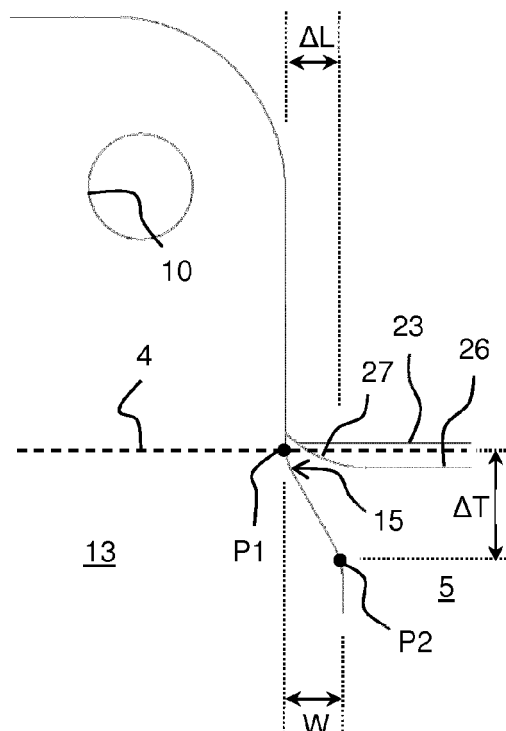


FIG. 9B



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Application Number
EP 13 19 8883

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