(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 598 054 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
22.01.2020 Bulletin 2020/04

(51) Int Cl.:
F28F 9/02 (2006.01) *F28D 9/00* (2006.01)

(21) Application number: **18275099.2**

(22) Date of filing: **19.07.2018**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **HS Marston Aerospace Limited**
Wolverhampton WV10 6QJ (GB)

(72) Inventors:
- **DESHPANDE, Aditya**
  Wolverhampton
  WV10 6QJ (GB)
- **ASTLEY, Stuart**
  Wolverhampton
  WV10 6QJ (GB)

(74) Representative: **Dehns**
St. Bride's House
10 Salisbury Square
London EC4Y 8JD (GB)

(54) FIN-PLATE HEAT EXCHANGER

(57) A fin-plate heat exchanger is arranged to allow heat to be exchanged between a first fluid and a second fluid. The fin-plate heat exchanger (1) comprises: a core (100) with first flow paths (200) for the first fluid and second flow paths (300) for the second fluid; a plurality of separating plates (101); a plurality of fin components (103); a plurality of first enclosure bars (203, 204, 206); and a plurality of second enclosure bars (305, 306). The heat exchanger (1) further comprises a manifold (400) arranged in fluid communication with each of the first flow paths (200) of the core (100). The manifold (400) and the core (100) are formed as one integral piece, said integral piece comprising a stack of laminate members (101, 201, 301, 501, 502) and said fin components (103). The plurality of laminate members (101, 201, 301, 501, 502) comprise: first fluid enclosure structures (201) each including a first manifold section (202) and said first enclosure bars (203, 204, 206); second fluid enclosure structures (301) each including at least one second enclosure bar (305, 306), at least some of the of the second fluid enclosure structures (301) comprising a second manifold section (302). The plurality of laminate members (101, 201, 301, 501, 502) also comprise the plurality of separating plates (101), with each separating plate (101 comprising a third manifold section (102), and each separating plate (101) separating each first enclosure structure (201) from adjacent second enclosure structures (301). The first, second and third manifold sections (202, 302, 102) are shaped to form the manifold (400) when the plurality of laminate members (101, 201, 301, 501, 502) are stacked.

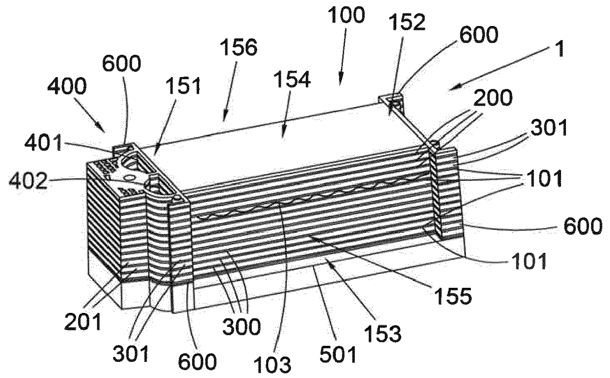

Fig. 1

EP 3 598 054 A1

Description

[0001] The present disclosure relates to a fin-plate heat exchanger and a method of manufacturing a fin-plate heat exchanger, particularly for use in aerospace applications.

[0002] A fin-plate heat exchanger is a known type of heat exchanger.

[0003] It typically comprises a core that has a plurality of first flow paths and a plurality of second flow paths. The first flow paths are in communication with a manifold that communicates a first fluid (such as oil) through the first flow paths. The second flow paths are arranged to allow a second fluid (such as air) to pass. The first and second flow paths are generally planar and are arranged in a stacked arrangement, where second flow paths are located above and below a given first flow path, and first flow paths are located above and below a given second flow path.

[0004] Separating the flow paths are separating plates that allow heat to transfer between the first and second flow paths.

[0005] To assist the transfer of heat, fins are provided in the first and second flow paths. The fins extend between adjacent separating plates. The fins are orientated in a direction to assist or guide fluid flow.

[0006] Adjacent separating plates are separated by enclosure bars. The enclosure bars act to enclose respective first and second flow paths. Together with the separating plates, the enclosure bars act to define the first and second flow paths in the core.

[0007] The fin-plate heat exchanger also comprises a manifold that is in fluid communication with the first flow paths, but is not in fluid communication with the second flow paths. The manifold can supply and/or receive the first fluid to and/or from the core.

[0008] Such a typical fin-plate heat exchanger is conventionally made in the following way.

[0009] The core is made by forming a stack of components. This is achieved by first providing a base plate. On top of the base plate, enclosure bars for the first fluid path are placed, and a fin component (such as a corrugated sheet) is placed. On top of these, a separating plate is placed. On top of this, enclosure bars for the second fluid path are placed, and a fin component (such as a corrugated sheet) is placed. On top of this, a separating plate is placed. This is repeated until the stack of a desired size is formed. To finish the stack, on top of the upper-most enclosure bars and the upper-most fin component, a top plate is placed.

[0010] The stack is then brazed together to form the core.

[0011] The manifold is made by a separate process, such as by casting, machining or fabrication.

[0012] The heat exchanger is then formed by welding the manifold and/or interface flanges to the core together.

[0013] However, the present inventors have identified a desire to provide a more reliable and light-weight heat exchanger that is quicker and cheaper to produce due to the elimination of welding process.

[0014] Viewed from a first aspect, the invention provides a fin-plate heat exchanger for allowing heat to be exchanged between a first fluid and a second fluid, the fin-plate heat exchanger comprising:
a core comprising:

- a plurality of first flow paths for the first fluid and a plurality of second flow paths for the second fluid;
- a plurality of separating plates, adjacent first and second flow paths being separated by respective separating plates;
- a plurality of fin components extending through respective first and second flow paths and extending between adjacent separating plates;
- a plurality of first enclosure bars extending between adjacent separating plates, the first enclosure bars being arranged to at least partially define the first flow path; and
- a plurality of second enclosure bars extending between adjacent separating plates, the second enclosure bars being arranged to at least partially define the second flow path, and

a manifold arranged in fluid communication with each of the first flow paths of the core, and characterised in that: the manifold and the core are formed as one integral piece, said integral piece comprising a stack of laminate members and said fin components, wherein the plurality of laminate members comprise:

- a plurality of first fluid enclosure structures for enclosing the first flow path, each first fluid enclosure structure comprising a first manifold section and said first enclosure bars;
- a plurality of second fluid enclosure structures for enclosing the second flow path, each second fluid enclosure structure comprising at least one second enclosure bar, and at least some of the of the second fluid enclosure structures comprising a second manifold section;
- the plurality of separating plates, each separating plate comprising a third manifold section, and each separating plate separating each first enclosure structure from adjacent second enclosure structures,
- wherein the first, second and third manifold sections are shaped to form the manifold when the plurality of laminate members are stacked.

[0015] The first manifold section may be on a first laminate member, the second manifold section may be on a second laminate member, and the third manifold section may be on a third laminate member, with the first ,second and third laminate members being stacked in sequence. This sequence may be repeated to build up a heat exchanger with multiple parallel flow paths formed via multiple sets of first, second and third laminate members.

[0016] The fin-plate heat exchanger may comprise at least one flange for mounting the heat exchanger to other components, wherein the manifold, the core and the at least one flange are formed as one integral piece, wherein each of the first enclosure structures, each of the separating plates and at least some of the second enclosure structures comprise respective flange portions, wherein the flange portions are shaped to form the at least one flange when the plurality of laminate members are stacked.

[0017] The integral piece may comprise the laminate members and the fin components brazed together.

[0018] Optionally, the manifold is not welded to the core.

[0019] Optionally the laminate members do not comprise fins.

[0020] The manifold may comprise manifold features for allowing the first fluid to be supplied to and/or received from the first flow paths, wherein the first, second and third manifold sections each comprise respective features that form the manifold features when the plurality of laminate members are stacked.

[0021] The fin-plate heat exchanger may comprise a base plate and a top plate, wherein the laminate members comprise the base plate and the top plate, wherein the base plate forms the lower-most layer of the stack and the top plate forms the upper-most layer of the stack, wherein the base plate and the top plate each comprise a fourth manifold portion and a core portion, wherein the base plate and the top plate are each shaped such that the core portion encloses the core and the fourth manifold portion encloses the manifold.

[0022] The laminate members may be produced by additive manufacturing and/or subtractive manufacturing.

[0023] The fin components are optionally not made by either additive manufacturing or subtractive manufacturing.

[0024] The invention further extends to a method of manufacturing a fin-plate heat exchanger, wherein the heat exchanger is as discussed above and the method comprises: stacking the laminate members and the fin components; and joining the laminate members and the fin components together to form the integral piece.

[0025] Optionally the method does not include joining the manifold and the core together.

[0026] At least some of the laminate members may be produced by additive manufacturing.

[0027] At least some of the laminate members may be produced by subtractive manufacturing.

[0028] In one example at least some of the laminate members are produced by subtractive manufacturing and the separating plates are produced by subtractive manufacturing.

[0029] The method may comprise removing excess material from the integral piece after the joining process.

[0030] Certain embodiments of the disclosure will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 shows an exemplary embodiment of the fin-plate heat exchanger;
Figures 2-4 show details of the components of the fin-plate heat exchanger of Figure 1;
Figure 5 shows another view of the of the fin-plate heat exchanger of Figure 1; and
Figure 6 shows an exemplary embodiment of a method of manufacturing a fin-plate heat exchanger.

As mentioned above, in a first aspect, disclosed is a fin-plate heat exchanger for allowing heat to be exchanged between a first fluid and a second fluid. The fin-plate heat exchanger comprises a core comprising: a plurality of first flow paths for the first fluid and a plurality of second flow paths for the second fluid; a plurality of separating plates, adjacent first and second flow paths being separated by respective separating plates; a plurality of fin components extending through respective first and second flow paths and extending between adjacent separating plates; a plurality of first enclosure bars extending between adjacent separating plates, the first enclosure bars being arranged to at least partially define the first flow path; and a plurality of second enclosure bars extending between adjacent separating plates, the second enclosure bars being arranged to at least partially define the second flow path. The fin-plate heat exchanger also comprises a manifold arranged in fluid communication with each of the first flow paths of the core. The fin-plate heat exchanger is characterised in that the manifold and the core are formed as one integral piece, said integral piece comprising a stack of laminate members and said fin components. The plurality of laminate members comprise: a plurality of first fluid enclosure structures for enclosing the first flow path, each first fluid enclosure structure comprising a first manifold section and said first enclosure bars; a plurality of second fluid enclosure structures for enclosing the second flow path, each second fluid enclosure structure comprising a second enclosure bar, and at least some of the of the second fluid enclosure structures comprising a second manifold section; the plurality of separating plates, each separating plate comprising a third manifold section, and each separating plate separating each first enclosure structure from adjacent second enclosure structures. The first, second and third manifold sections are shaped to form the manifold when the plurality of laminate members are stacked. Thus, first manifold section may be on a first laminate member, the second manifold section may be on a second laminate member, and the third manifold section may be on a third laminate member, with the first ,second and third laminate members being stacked in sequence. This sequence may be repeated to build up a heat exchanger with multiple parallel flow paths formed via multiple sets of first, second and third laminate members. This fin-plate heat exchanger should be more reliable than conventional fin-plate heat exchangers due to the elimination of welding process. In conventional fin-plate heat exchangers, the manifold and core are formed separately, and are then joined together, for example by a welding process. However, the inventors have identified that such welding joints are susceptible to thermomechanical fatigue cracking. The present heat exchanger does require any such weld, and therefore does suffer such reliability issues.

[0031] Further, the present fin-plate heat exchanger may be lighter in weight than conventional fin-plate heat exchangers, which is of particular relevance in industries such as aerospace. Due to the presence of the weld (which is a potential weakness, as mentioned above) conventional fin-plate heat exchangers may be built heavier than the present heat exchanger.

[0032] Further still, the present fin-plate heat exchanger may be built more rapidly and cheaply than conventional fin-plate heat exchangers. Since both the manifold and the core are made as one integral piece from the laminate members, there is no need to manufacture the manifold and the core separately and then join them together, which reduces construction time. Further, the laminate members can be manufactured very quickly (for example from additive or subtractive manufacturing processes) and the fin components can be provided as standard components. Thus, all of the components that make up the heat exchanger can be made or provided very quickly. In addition, the form of the laminate members can be varied quickly, which allows great flexibility and quick changing of the overall heat exchanger design, especially in comparison to when a conventional manifold is made from a cast in a mould or machined from solid or fabricated joining individual components.

[0033] As mentioned above, the present heat exchanger is a fin-plate heat exchanger. This is a specific type of heat exchanger and is different to other types of heat exchanger, such as microchannel heat exchangers or heat exchangers where pins (or other heat conducting elements) are used in the flow paths.

[0034] The heat exchanger may be arranged to exchange heat only between the first and second fluids, i.e. there may be no additional fluids present.

[0035] As can be understood from the description of the core above, the core of the present heat exchanger may be similar to or identical to the cores of conventional heat exchangers. The inventors have not intended to alter the design of the core. Indeed, one of the purposes of the present invention is to produce a fin-plate heat exchanger that has the same (or a similar) form to conventional fin-plate heat exchangers, but also has the advantages listed above. The inventors have achieved this by the innovative design of the laminate members discussed herein.

[0036] Thus, the core may comprise a plurality of first flow paths arranged in a layered fashion. Between said first flow paths may be second flow paths. The first and second flow paths may be separated by separating plates. The first and second flow paths may be generally planar and the first and second fluids may move in parallel to said planes.

[0037] The core may comprise a first end and a second end, the first end being the end to which the manifold is attached and the second end being opposite said first end. The core may comprise a bottom and a top. The top and the bottom being the extremes of the core in the direction generally normal to the direction of the stack (i.e. generally parallel to the normal of the plane defined by the separating plates, see below). The core may comprise a first side and a second side, the first and second sides extending between the top and bottom and the first and second ends, and being opposite each other. The core may be shaped in a general cuboid-shape.

[0038] Adjacent first and second flow paths may be in thermal communication with each other (e.g. via the fins and the separating plates). For example, one first flow path may be in communication with two second flow paths (the second flow paths above and below the first flow path); and one second flow path may be in communication with two first flow paths (the first flow paths above and below the first flow path).

[0039] The separating plates may be generally planar (herein "planar" may mean totally flat, or may be a curved plane). The first and second flow paths may be correspondingly planar. The separating plates (and hence the flow paths) may be stacked in a way such that they are separated from each other in a direction generally normal to said plane. The separating plates may have a rectangular area.

[0040] Each fin component may be an integral piece comprising multiple fins (such as a corrugated sheet). There may be only one integral piece per flow path. However, there may be more than one. Alternatively, each fin component can comprise only one fin, and a plurality of such components are provided separately within each flow path.

[0041] The fin components may be placed between adjacent separating plates and hence in said flow paths. The fins may guide the fluid in said flow paths.

[0042] As is known, fins are generally planar heat transfer elements that extend between adjacent separating plates and extend generally in the direction of fluid flow. They are different from pins and other heat transfer elements.

[0043] The first enclosure bars may be located at the first and second sides of the core. The first enclosure bars may be located between separating plates at the periphery of the separating plates. There may be one first enclosure bar between two adjacent separating plates at the first side and another first enclosure between the same two adjacent separating plates at the second side. There may not be any second enclosure bars present between said separating plates. There may be second enclosure bars present on the other side of both said separating plates. The first enclosure bars and the separating plates define a first flow path where at least one end of the core is open.

[0044] The second enclosure bars may be located at the first and second ends of the core. The second enclosure bars may be located between separating plates at the periphery of the separating plates. There may be one second enclosure bar between two adjacent separating plates at the first end and another second enclosure between the same two adjacent separating plates at the second end. There may not be any first enclosure bars present between said separating plates. There may be first enclosure bars present on the other side of both said separating plates. The second enclosure bars and the separating plates define a first flow path where at least one side of the core is open.

[0045] Stated differently, a given separating plate will be separated from an adjacent separating plate above/below by first enclosure bars and by an adjacent separating plate below/above by second enclosure bars.

[0046] The manifold is for supplying the first fluid to and/or receiving the first fluid from the first fluid paths. It is not in communication with the second fluid paths.

[0047] The manifold may be located at the first end of core.

[0048] There may be only one manifold. In this case, the second end of the core of the first flow paths may be enclosed by another first enclosure bar. The manifold may comprise a supply and a return path for the first fluid. There may be a guiding structure present in the core to guide the fluid through the first flow paths from the supply to the return path.

[0049] There may be two manifolds. In this case, the manifolds may be present at either end of the core.

[0050] As mentioned above, in the present fin-plate heat exchanger, the manifold and the core are formed as one integral piece. This means that they are not two separate pieces that have been joined together, for example by welding. Rather, they are formed in the same formation process (such as the brazing process mentioned below).

[0051] There may also be flanges formed in the same integral piece, with the flanges acting as interface flanges. These interface flanges may be formed by interface flange sections provided on some or all of the laminate members.

[0052] The stack of laminate members are laminated together. Lamination is known term in the art and is not discussed herein. The stack may be referred to as a laminated stack.

[0053] Each laminate member may be an integral piece, i.e. they are formed in one process and do not comprise any joints, such as welds.

[0054] The stack may be arranged by having separating plates separated by alternating first and second enclosure structures.

[0055] The first manifold sections of respective first enclosure structures may be the same as or different to each other. The second manifold sections of respective second enclosure structures may be the same as or different to each other (and the same as or different to the first manifold sections). The third manifold sections of respective separating plates may be the same as or different to each other (and the same as or different to the first and second manifold sections). The form of the respective first, second and third manifold sections can be such that, when the laminate members are stacked appropriately, a manifold with the correct form/features results. The first, second and third manifold sections are effectively cross-section slices of the overall manifold, such that when they are placed together the manifold is formed. Thus, first manifold section may be on a first laminate member, the second manifold section may be on a second laminate member, and third manifold section may be on a third laminate member, with the first ,second and third laminate member being stacked in sequence. This sequence may be repeated to build up a heat exchanger with multiple parallel flow paths formed via multiple sets of first, second and third laminate members.

[0056] Having the laminate members comprise such manifold sections is advantageous, not only because the manifold and the core can be formed as an integral piece, but also because it means the features of the manifold (e.g. the pipes/openings/etc.) do not need to be machined into the manifold after the stack is laminated. Further it allows the form of the manifold to be varied easily from one heat exchanger to the next.

[0057] The fin-plate heat exchanger may comprise at least one flange for mounting the heat exchanger to other components. Such other components may be nearby supporting structures, such as an airframe, or other components such as ducts and pipes.

[0058] The manifold, the core and the at least one flange may be formed as one integral piece. This may be achieved by having each of the first enclosure structures, each of the separating plates and at least some of the second enclosure structures (and preferably each of the second enclosure structures) comprise respective flange portions, wherein the flange portions are shaped to form the at least one flange when the plurality of laminate members are stacked.

[0059] Conventionally, such flanges are welded onto the core/manifold after the core is formed. However, by providing flange portions in the laminated members, the flanges can be formed at the same time as the core and can be integral with the core. This can improve reliability, reduce construction time and reduce weight. Thus, the flange may not be joined (e.g. welded) to the remainder of the heat exchanger.

[0060] There may be a plurality of flanges each formed by a respective plurality of flange portions in the laminate members. There may be (exactly) four flanges, one located proximate each corner of the core.

[0061] The integral piece may comprise (or consist of) the laminate members and the fin components adhered (e.g. brazed) together. There may of course be some adhering (e.g. brazing or bonding) material present too.

[0062] As mentioned above, the manifold may not be joined (e.g. welded) to the core. Said flange(s) may not be joined (e.g. welded) to the remainder of the heat exchanger. There may be no flange or manifold joined (e.g. welded) to the remainder of the heat exchanger. There may be no weld present in the heat exchanger.

[0063] The laminate members may not comprise any fins (or any other secondary assisting heat transfer surfaces, such as pins). Rather, the fins may only be provided in the fin components, which may not be laminated members. The fins may be provided in a conventional way, such as by a corrugated sheet. The fins may be placed in the stack (between separating plates) and adhered (e.g. brazed) together with the laminated members.

[0064] As mentioned above, the manifold may comprise manifold features for allowing the first fluid to be supplied to and/or received from the first flow paths. The first, second and third manifold sections may each comprise respective features that form the manifold features when the plurality of laminate members are stacked.

[0065] The manifold features may comprise fluid paths, pipes, openings, etc. for the first fluid.

[0066] If only one manifold is present in the heat exchanger, the manifold features may comprise a supply fluid path and a return fluid path, each being open to the first fluid paths.

[0067] If two manifolds are present (e.g. one at each end of the core), then a first manifold may comprise a supply fluid path and a second manifold may comprise a return fluid path, the supply and the return paths being open to the first fluid paths.

[0068] The fin-plate heat exchanger may comprise a base plate and a top plate. These may also be referred to as "side plates" in the art. The base plate may be located at the bottom of the stack and the top plate may be located at the top of stack.

[0069] The laminate members may comprise the base plate and the top plate. The base plate and the top plate may each comprise a fourth manifold portion and a core portion. The base plate and the top plate may be each shaped such that the core portion encloses the core and the manifold portion encloses the manifold.

[0070] The top and the base plates may effectively provide some external structure to the heat exchanger and may seal the manifold and/or the core.

[0071] The laminate members may consist of the first enclosure structures, the second enclosure structure, the separating plates, the base plate and the top plate. Thus, the integral member may be formed solely of the first enclosure structures, the second enclosure structure, the separating plates, the base plate, the top plate and the fin components (and some adhering material, such as brazing material).

[0072] The laminate members may be produced by additive manufacturing (such as laser powder bed fusion or energy metal deposition) and/or subtractive manufacturing (such as etching, laser cutting, water jet cutting, wire eroding or highspeed machining). Different laminated members can be made by the same or different methods. The top plate, the base plate, the first enclosure structures or the second enclosure structures may be made by either additive manufacturing or subtractive manufacturing. However, the separating plates are preferably made by subtractive manufacturing.

[0073] The present heat exchanger allows a large proportion of its constituent components to be made by these methods. Conventional methods do not allow this. This is advantageous since it allows a great deal of flexibility in design of heat exchanger, and the heat exchanger's form can be varied very quickly. Further, it can increase the speed of the manufacture.

[0074] The fin components may be manufactured by a different technique to the laminate members. Thus, they may be made during a separate process. In some examples fin components are not made by additive manufacturing or by subtractive manufacturing. Rather, the fins may be made (or supplied) in a conventional way for heat exchanger finstock (for example by pressing/bending a sheet to form a corrugated and/or perforated sheet).

[0075] The present heat exchanger allows the use of conventional fin components as one of its constituent components. This is advantageous since it allows the structure of the heat exchanger to be made quickly and strongly (as mentioned above), but can still use the conventional fin components, which are cheap and easy to make/supply.

[0076] As can be appreciated, the inventors have devised a sort of "hybrid" technology, that is somewhere between producing a fin-plate heat exchanger purely from a rapid manufacture process (such as additive manufacturing), producing a fin-plate heat exchanger by a pure laminated process (such as in EP 2474803, discussed below) and by producing a fin-plate heat exchanger by conventional means (as discussed in the background section).

[0077] The present method is advantageous over these alternatives since it is quicker and more reliable than conventional means, but is more straightforward than using pure rapid manufacture (which may struggle to produce such a complex fin-plate heat exchanger) or by using a pure laminated process (where the fins would be required to be part of each laminate member making up a given layer). Thus, the inventors have found an improved way of manufacturing a fin-plate heat exchanger.

[0078] For instance, it may be known (for example from US 2015/260459 or EP 2474803) to manufacture a core and a manifold as one integral piece from laminate members.

[0079] However, in the prior art there is no teaching or suggestion of using fin components in both the first and second flow paths in such a laminated core structure. Rather, in the prior art, whenever a laminated integral core and manifold are produced, the heat transfer elements used are pins or the like.

[0080] Further, these prior art heat exchangers are made from a pure laminated process, where the heat transfer elements (the pins) are integral parts of each laminated member. Pins are used as the heat transfer elements because they lend themselves to being formed in this laminated way. However, it is much more difficult to produce fins in a laminated way (which is why it has not been done in the prior art).

[0081] In contrast to these prior art examples, in the present heat exchanger the fins are provided as separate to the laminate members (e.g. the fins are provided as conventional fin components (e.g. corrugated sheets) whereas the laminate members are provided as rapidly-produced (e.g. subtractive or additive manufactured) components). Thus, the present inventors have developed a "hybrid" type technology that is that is somewhere between producing a fin-plate heat exchanger purely from a rapid manufacture process, producing a fin-plate heat exchanger by a pure laminated process, and producing a fin-plate heat exchanger by conventional means.

[0082] The fin-plate heat exchanger may be for use in an aircraft. For instance, it may be for use in an aircraft engine, or possibly in an air management system in an aircraft.

[0083] The fin-plate heat exchanger may be for use with a first fluid that can vary between -40°C to 210°C. The fin-plate heat exchanger may be for use with a second fluid that can very between -50°C to 100°C. The fin-plate heat exchanger may be for use with a first fluid that can vary between 3 kPa to 150 kPa. The fin-plate heat exchanger may be able to function over both of these ranges, and possibly beyond. The fin-plate heat exchanger may comprise the first and second fluids.

[0084] The first fluid may be a liquid, such as oil and the second fluid may be a gas, such as air or any combinations thereof.

[0085] In a second aspect, provided is a method of manufacturing a fin-plate heat exchanger. The heat exchanger may be the heat exchanger of the first aspect. The method may comprise stacking the laminate members and the fin components; and adhering (e.g. brazing) the laminate members and the fin components together to form the integral piece.

[0086] The stacking may be as set out above, i.e. a first enclosure structure, then a separating plate, then a second enclosure structure, then a separating plate, then a first enclosure, etc.

[0087] Stacking the laminate members may comprise placing a first (or second) enclosure structure on top of the base plate; placing a separating plate on top of the first (or second) enclosure structure; placing a second (or first) enclosure structure on top of the separating plate; placing a separating plate on top of the second (or first) enclosure structure; and then repeating the first enclosure structure, separating plate, second enclosure structure pattern until the core is complete. Then the top plate is placed on the upper most enclosure structure (which may be a first or a second enclosure structure).

[0088] In addition to these components, adhering (e.g. brazing) material may also be added during the stacking. For instance, adhering material may be added between the base plate and the lower most enclosure structure. Adhering material may be added between the top plate and the upper most enclosure structure.

[0089] Adhering material may be added between each layer of the stack. However, preferably it is only added in the positions mentioned in the paragraph above.

[0090] To bond the remainder of the structure, adhering material may be provided on both sides of the separating plates (i.e. the separating plates may be formed from a sheet of material that already has adhering material cladded onto both of its upper and lower surfaces).

[0091] The method may not include joining (e.g. welding) the manifold and the core together. As mentioned above, conventionally the manifold and the core of a fin-plate heat exchanger are manufactured separately, and then welded together. The inventors have devised a method where this step may not be necessary.

[0092] The method may comprise producing at least some of the laminate members by additive manufacturing. The first enclosure structures may be produced by additive manufacturing. The second enclosure structures may be produced by additive manufacturing. The top and base plates may be produced by additive manufacturing.

[0093] Additionally/alternatively, the method may comprise producing at least some of the laminate members by subtractive manufacturing. The first enclosure structures may be produced by subtractive manufacturing. The second enclosure structures may be produced by subtractive manufacturing. The top and base plates may be produced by subtractive manufacturing.

[0094] The method may comprise producing the separating plates by subtractive manufacturing. This is preferable (instead of additive manufacturing), since the separating plates may be made from sheets where adhering material is already present. Such a material would be difficult to produce by additive manufacture.

[0095] The method may comprise removing excess material from the integral piece after the adhering process. There may be excess material present near the manifold and in other places, so as to provide enough structural integrity in the stack during adhering (where the stack may be held under pressure). Further, there may be excess material in the flange(s), which may be too big for their intended purpose. Further, holes can be drilled into the flange(s) so that they can be attached (e.g. bolted) to other components.

[0096] The method may not comprise machining the manifold or the core after the integral piece is formed. There is no need to do so.

[0097] The method may comprise producing a first laminated heat exchanger using any of the methods above, and then producing a second laminated heat exchanger using any of the methods above. The first and the second laminated heat exchanger may differ in form, e.g. they be of different sizes, have different dimensions, have different manifold features, have different areas and thicknesses of flow paths, etc.

[0098] Due to the flexibility of the present method, the time taken to produce two such different heat exchangers may be dramatically reduced in comparison to conventional methods.

[0099] Turning now to Figure 1, shown is a fin-plate heat exchanger 1 in accordance with an embodiment of the present fin-plate heat exchanger.

[0100] The heat exchanger 1 comprises a core 100. The core 100 comprises a plurality of first flow paths 200 for a first fluid and a plurality of second flow paths 300 for the second fluid. The first 200 and second 300 flow paths are arranged in an alternating stack and are separated by a plurality of separating plates 101. A plurality of fin components 103 extend through respective first 200 and second 300 flow paths and extend between adjacent separating plates 101. In Figure 1, only the fin components 103 in the second flow path 300 are shown, since the fin components 103 in the first flow path 200 cannot be seen.

[0101] First enclosure structures 201 act in cooperation with the separating plates 101 to define the first flow paths 200.

[0102] Second enclosure structures 301 act in cooperation with the separating plates 101 to define the second flow paths 300.

[0103] The core 100 comprises a first end 151 and a second end 152; a bottom 153 and a top 154; and a first side 155 and a second side 156.

[0104] The fin-plate heat exchanger 1 also comprises a manifold 400 arranged in fluid communication with each of the first flow paths 200 of the core 100.

[0105] The manifold 400 comprises manifold features, such as supply line 401 and a return line 402 for supplying the first fluid to the first fluid paths 200 and receiving fluid from the first fluid paths 200 respectively.

[0106] The fin-plate heat exchanger 1 comprises flanges 600. The flanges 600 are for attaching the heat exchanger 1 to other adjacent components.

[0107] The manifold 400, the flanges 600 and the core 100 are formed as one integral piece.

[0108] The integral piece comprises a stack of laminate members 101, 501, 502, 201, 301 and said fin components 103.

[0109] The plurality of laminate members 101, 501, 502, 201, 301 comprise: the first fluid enclosure structures 201; the second fluid enclosure structures 301; the plurality of separating plates 101; a base plate 501 and a top plate 502 (not shown in Figure 1).

[0110] The stack is formed by placing a first enclosure structure 201 and at least one fin component (not shown) on top of the base plate 501. On top of the first enclosure 201 and the at least one fin component, a separating plate 101 is placed. On top of the separating plate 101, a second enclosure structure 301 and a fin component 103 is placed. On top of these, another separating plate 101 is placed. This pattern is then repeated until the top 154 of the heat exchanger is reached, when a top plate 502 is placed on top of the uppermost enclosure structure(s) and fin component(s)..

[0111] As mentioned above, the stack may be brazed together to form the integral piece.

[0112] Regarding Figure 2, an exemplary first enclosure structure 201 is shown in more detail.

[0113] The first enclosure structure 201 comprises a manifold section 202. The manifold section comprises manifold feature cut outs 208, 209. The manifold section 202 is shaped such that, when the first enclosure structure 201 is placed in the stack, the manifold 400 with the correct features 401, 402 is formed.

[0114] The first enclosure structure 201 also comprises a first enclosure bar 203 arranged to close off the first side 155 of the first fluid path 200 when placed between two separating plates 101.

[0115] The first enclosure structure 201 also comprises a second enclosure bar 204 arranged to close off the second side 156 of the first fluid path 200 when placed between two separating plates 101.

[0116] The first enclosure structure 201 may also comprise a third enclosure bar 206 arranged to close off the second end 152 of the first fluid path 200 when placed between two separating plates 101.

[0117] The first enclosure structure 201 may also comprise a guiding structure 207 arranged to guide the flow of the first fluid through the first flow path 200 from the supply 401 to the return 402 of the manifold.

[0118] The first enclosure structures 201 leave the first end 151 of the first flow path 200 open.

[0119] Other guides may be present, or no guides may be present. For instance, it may be that there are two manifolds present, one at either end 151, 153.

[0120] The first enclosure structure 201 also comprises a plurality of flange portions 210 arranged such that, when the first enclosure structure 201 is placed in the stack, the flanges 600 are formed.

[0121] Each first enclosure structure 201 may be the same as one another, or may be different. The precise form of each first enclosure structure will depend on the desired shape and features of the heat exchanger 1.

[0122] Regarding Figures 3a and 3b, shown are exemplary second enclosure structures 301. The enclosure structures of Figures 3a and 3b work in combination with each other to close respective ends 151, 152 of the core 100 between two separating plates 101 so as to define a given second flow path. In the example shown here, the second enclosure structure 301 shown in Figure 3a closes the second end 152 and the second enclosure structure 301 shown in Figure 3b closes the first end 151 of the same second flow path 300.

[0123] Regarding Figure 3a, the first enclosure structure 301 comprises a second enclosure bar 306 arranged to close off the second end 152 of the second fluid path 300 when placed between two separating plates 101.

[0124] Regarding Figure 3b, the second enclosure structure 301 comprises a manifold section 302. The manifold section comprises manifold feature cut outs 308, 309. The manifold section 302 is shaped such that, when the first enclosure structure 301 is placed in the stack, the manifold 400 with the correct features 401, 402 is formed.

[0125] The second enclosure structure 302 also comprises a first enclosure bar 305 arranged to close off the first end 151 of the second fluid path 300 when placed between two separating plates 101.

[0126] The second enclosure structures 301 leave the first and second sides 155, 156 of the second flow path 300 open.

[0127] The second enclosure structures 301 also comprise a plurality of flange portions 310 arranged such that, when the second enclosure structures 301 are placed in the stack, the flanges 600 are formed.

[0128] Each second enclosure structure 301 of Figure 3a may be the same as one another, or may be different to each other. Each first enclosure structure 301 of Figure 3b may be the same as one another, or may be different. The precise form of each first enclosure structure will depend on the desired shape and features of the heat exchanger 1.

[0129] Regarding Figure 4, an exemplary separating plate 101 is shown in more detail.

[0130] The separating plate 101 comprises a manifold section 102. The manifold section comprises manifold feature cut outs 108, 109. The manifold section 102 is shaped such that, when the separating plate 101 is placed in the stack, the manifold 400 with the correct features 401, 402 is formed.

[0131] The separating plate 101 has a core portion 104 that is solid (unbroken) and extends from the first end 151 to the second end 152 and from the first side 155 to the second side 156.

[0132] The separating plate 101 also comprises a plurality of flange portions 110 arranged such that, when the separating plate 101 is placed in the stack, the flanges 600 are formed.

[0133] Each separating plate 101 may be the same as one another, or may be different. The precise form of each separating plate 101 will depend on the desired shape and features of the heat exchanger 1.

[0134] The top and base plates 501, 502 are not shown in detail, but may be similar to the separating plate 101, but without the manifold features 108, 109 (i.e. the top and base plates 501, 502 may be solid (unbroken) so as to close the manifold 400 and the core 100).

[0135] Figure 5 shows a completed fin-plate heat exchanger 1. This is largely identical to the fin-plate heat exchanger 1 shown in Figure 1, except the top plate 502 is also shown. Further, excess material (such as the honey-comb material in the manifold sections 102, 202, 402) have been removed, and holes have been drilled in the flange.

[0136] The fin-plate heat exchanger 1 of the above embodiment comprises only one manifold 400. However, it may be possible for two manifolds 400 to be present, one at each end 151, 152 of the core. In this case, one manifold may be for supply and one may be for return of the first fluid. To achieve this, additional manifold sections will be needed in the laminated members, and the manifold features of each will differ from what is shown in the Figures. For instance, third enclosure bar 206 may need to be replaced with a manifold section; a manifold section may be needed to be added to the enclosure bar 306; and a manifold section may need to be added at the second end 152 of the separating plate 101. In this case, there may be no need for guide 207.

[0137] Regarding Figure 7, it shows in more detail an exemplary first flow path 200 defined by an exemplary first enclosure structure 201. The first flow path comprises three fin components 103a, 106b, 103c.

[0138] The first fin component 103a extends from the manifold section 202 in a direction from the first end 151 toward the second end 152. The fins of the first fin component 103a are orientated in this direction, thus guiding fluid away from the supply line 401 of the manifold 400 between the second enclosure bar 204 and the guiding structure 207.

[0139] The second fin component 103b extends from the manifold section 202 in a direction from the first end 151 toward the second end 152. The fins of the second fin component 103b are orientated in this direction, thus guiding fluid toward the return line 402 of the manifold 400 between the first enclosure bar 203 and the guiding structure 207. The guiding structure fluidly separates the first and second fin structures 103a, 103b.

[0140] The third fin component 103c extends between the first and second fin components 103a, 103b in a direction generally perpendicular to the direction of the first and second fin components 103a, 103b (i.e. the fins of the third fin component 103c are generally parallel to and proximate to the second end 152 of the heat exchanger). The third fin component 103c guides the fluid from the first fin component 103a to the second fin component 103b between the third enclosure bar 206 and the guiding structure 207.

[0141] Each of the first flow paths may comprise similar or identical fin components 103a, 103b, 103c.

[0142] The fin component 103 of the second flow paths may be a single component. It may simply extend, and guide the second fluid, from the first side 155 to the second side 156 between the first and second enclosure bars 305, 306 of the second enclosure structure 301.

[0143] Regarding Figure 6, a method of manufacturing the fin-plate heat exchanger is schematically shown.

[0144] In a first step 901, the laminate members 101, 201, 301, 501, 502 are produced. This may occur by additive or subtractive manufacturing.

[0145] In a second step 902, the fin components 103 are formed. This may be achieved by cutting a corrugated sheet to size, and/or by punching a flat sheet such that corrugated fins are produced.

[0146] In a third step 903, the laminate members 101, 201, 301, 501, 502 and the fin components 103 are stacked. Possibly some brazing material is also placed in appropriate places in the stack.

[0147] In a fourth step 904, the stack is brazed to from the integral piece.

[0148] In a fifth step 905, excess material is cut off the integral piece.

[0149] In a sixth step 906, ancillary components such as relief valves are fitted.

[0150] This process can be repeated for a similarly-shaped or a differently-shaped fin-plate heat exchanger.

Claims

1. A fin-plate heat exchanger (1) for allowing heat to be exchanged between a first fluid and a second fluid, the fin-plate heat exchanger (1) comprising:
a core (100) comprising:

a plurality of first flow paths (200) for the first fluid and a plurality of second flow paths (300) for the second fluid;
a plurality of separating plates (101), adjacent first and second flow paths (200, 300) being separated by respective separating plates (101);
a plurality of fin components (103) extending through respective first and second flow paths (200, 300) and extending between adjacent separating plates (101);
a plurality of first enclosure bars (203, 204, 206) extending between adjacent separating plates (101), the first enclosure bars (203, 204, 206) being arranged to at least partially define the first flow path (200); and
a plurality of second enclosure bars (305, 306) extending between adjacent separating plates (101), the second enclosure bars (305, 306) being arranged to at least partially define the second flow path (300), and

a manifold (400) arranged in fluid communication with each of the first flow paths (200) of the core (100), and **characterised in that**:
the manifold (400) and the core (100) are formed as one integral piece, said integral piece comprising a stack of laminate members (101, 201, 301, 501, 502) and said fin components (103), wherein the plurality of laminate members (101, 201, 301, 501, 502) comprise:

a plurality of first fluid enclosure structures (201) for enclosing the first flow path (200), each first fluid enclosure structure (201) comprising a first manifold section (202) and said first enclosure bars (203, 204, 206);
a plurality of second fluid enclosure structures (301) for enclosing the second flow path (300), each second fluid enclosure structure comprising at least one second enclosure bar (305, 306), and at least some of the of the second fluid enclosure structures (301) comprising a second manifold section (302);
the plurality of separating plates (101), each separating plate (101) comprising a third manifold section (102), and each separating plate (101) separating each first enclosure structure (201) from adjacent second enclosure structures (301),

wherein the first, second and third manifold sections (202, 302, 102) are shaped to form the manifold (400) when the plurality of laminate members (101, 201, 301, 501, 502) are stacked.

2. A fin-plate heat exchanger as claimed in claim 1, further comprising at least one flange (600) for mounting the heat exchanger (1) to other components, wherein the manifold (400), the core (100) and the at least one flange (600) are formed as one integral piece, wherein each of the first enclosure structures (201), each of the separating plates (101) and at least some of the second enclosure structures (301) comprise respective flange portions (210, 310, 110), wherein the flange portions (210, 310, 110) are shaped to form the at least one flange (600) when the plurality of laminate members (101, 201, 301, 501, 502) are stacked.

3. A fin-plate heat exchanger as claimed in claim 1 or 2, wherein the integral piece comprises the laminate members (101, 201, 301, 501, 502) and the fin components (103) brazed together.

4. A fin-plate heat exchanger as claimed in any preceding claim, wherein the manifold (400) is not welded to the core (100).

5. A fin-plate heat exchanger as claimed in any preceding claim, wherein the laminate members (101, 201, 301, 501, 502) do not comprise fins.

6. A fin-plate heat exchanger as claimed in any preceding claim, wherein the manifold (400) comprises manifold features (401, 402) for allowing the first fluid to be supplied to and/or received from the first flow paths (200), and wherein the first, second and third manifold sections (202, 302, 102) each comprise respective features (208, 209, 308, 309, 108, 109) that form the manifold features (401, 402) when the plurality of laminate members (101, 201, 301, 501, 502) are stacked.

7. A fin-plate heat exchanger as claimed in any preceding claim, further comprising a base plate (501) and a top plate (502), wherein the laminate members (101, 201, 301, 501, 502) comprise the base plate (501) and the top plate (502), wherein the base plate (501) forms the lower-most layer of the stack and the top plate (502) forms the upper-most layer of the stack, wherein the base plate (501) and the top plate (502) each comprise a fourth manifold portion and a core portion, wherein the base plate (501) and the top plate (502) are each shaped such that the core portion encloses the core (100) and the fourth manifold portion encloses the manifold (400).

8. A fin-plate heat exchanger as claimed in any preceding claim, wherein the laminate members (101, 201, 301, 501, 502) are produced by additive manufacturing and/or subtractive manufacturing.

9. A fin-plate heat exchanger as claimed in any preceding claim, wherein the fin components (103) are not made by additive manufacturing or subtractive manufacturing.

10. A method of manufacturing a fin-plate heat exchanger, wherein the heat exchanger is the heat exchanger of any of the preceding claims, the method comprising:

stacking the laminate members (101, 201, 301, 501, 502) and the fin components (103); and joining the laminate members (101, 201, 301, 501, 502) and the fin components (103) together to form the integral piece.

11. A method as claimed in claim 10, wherein the method does not include joining the manifold (400) and the core (100) together.

12. A method as claimed in claim 10 or 11, comprising producing at least some of the laminate members (101, 201, 301, 501, 502) by additive manufacturing.

13. A method as claimed in claim 10, 11 or 12, comprising producing at least some of the laminate members (101, 201, 301, 501, 502) by subtractive manufacturing.

14. A method as claimed in claim 13, comprising producing the separating plates (101) by subtractive manufacturing.

15. A method as claimed in any of claims 10 to 14, comprising removing excess material from the integral piece after the joining process.

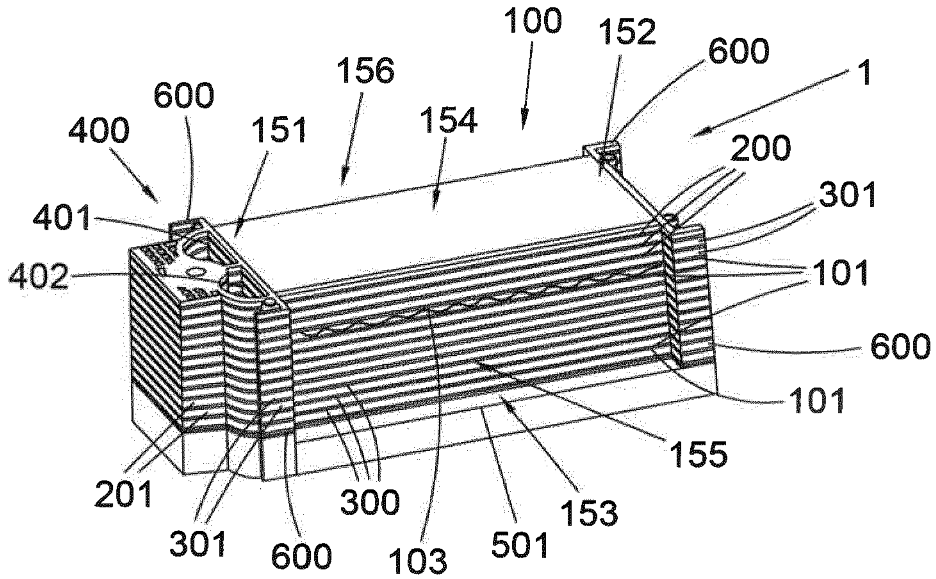
100
152
600
1
156
154
600
151
400
200
401
301
402
101
600
101
155
201
300
153
301
600
103
501

Fig. 1

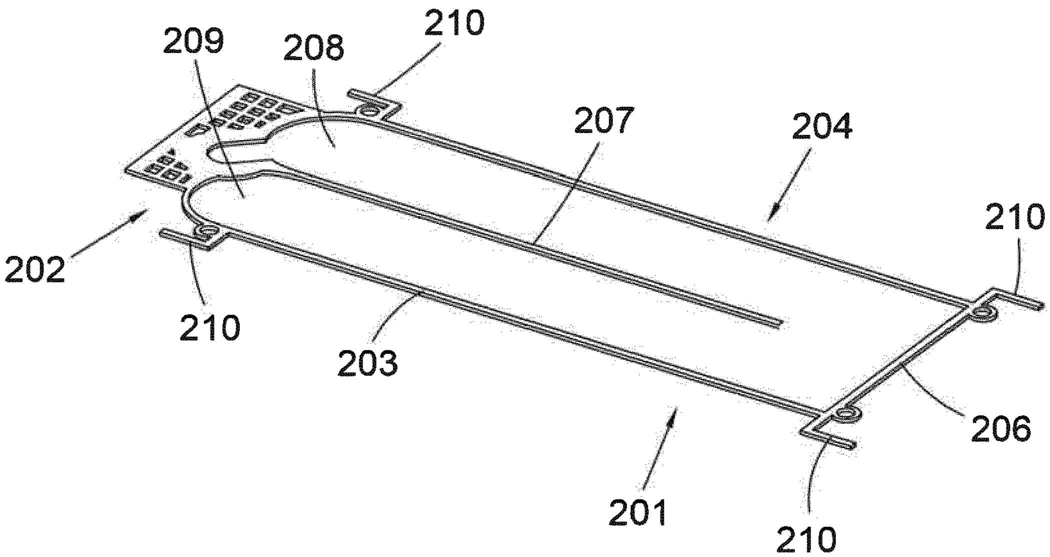
209
208
210
207
204
210
202
210
203
206
201
210

Fig. 2

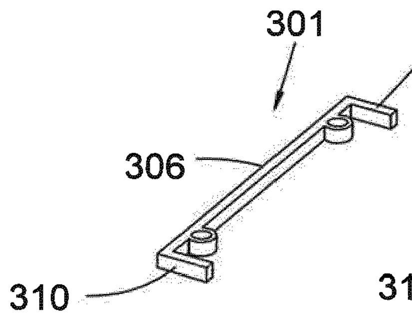

Fig. 3a

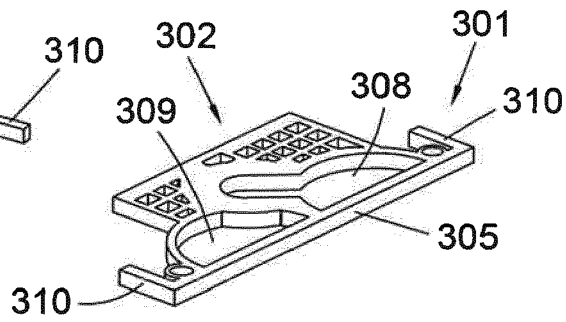

Fig. 3b

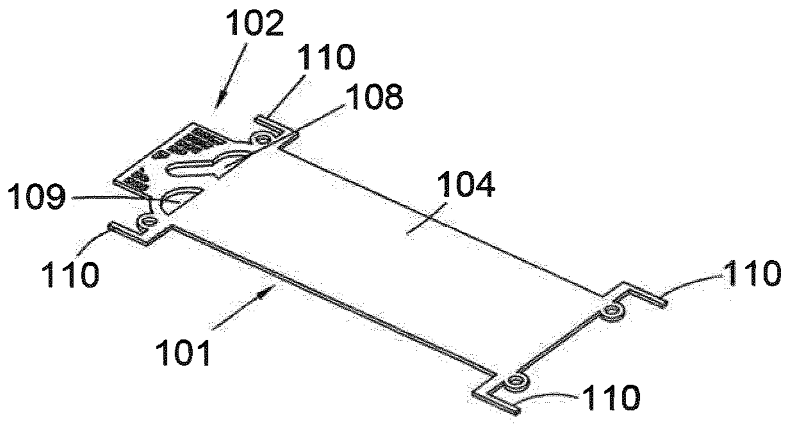

Fig. 4

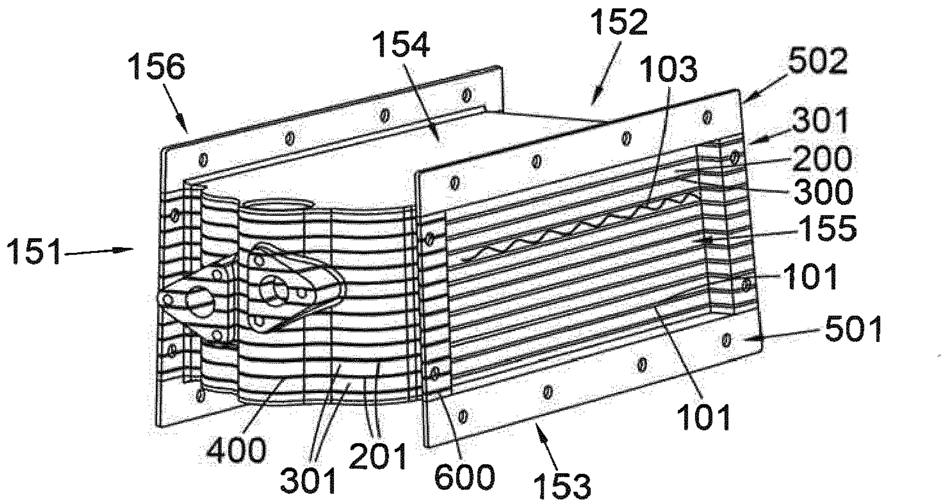

Fig. 5

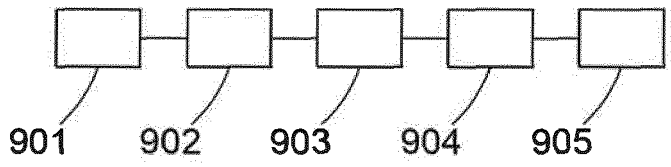

Fig. 6

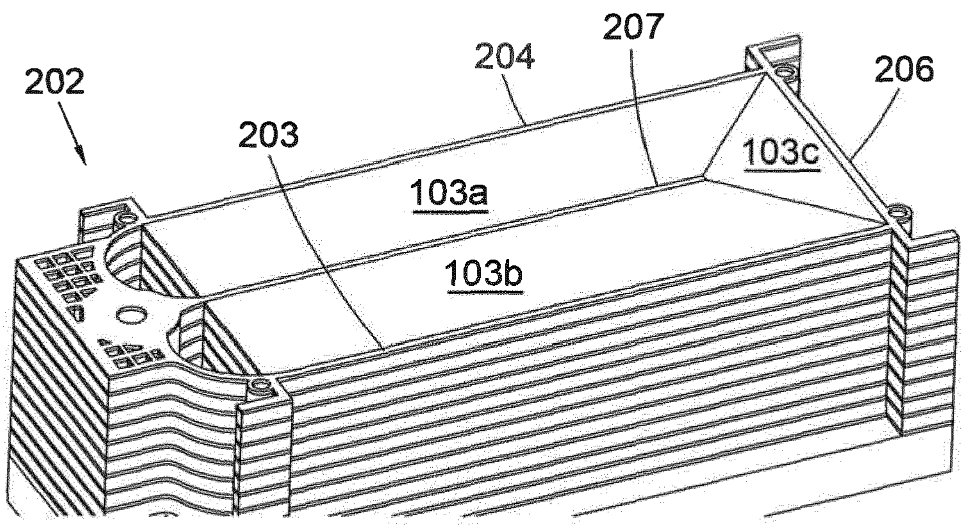

Fig. 7

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 18 27 5099

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2006/032251 A1 (WAKITA NAOSHI [JP] ET AL) 16 February 2006 (2006-02-16) * the whole document * -----	1,3-7, 9-11,15 2,8, 12-14	INV. F28F9/02 F28D9/00
Y,D	EP 2 474 803 A2 (HS MARSTON AEROSPACE LTD [GB]) 11 July 2012 (2012-07-11) * paragraph [0023]; figure 2 * -----	2	
Y	US 2018/015539 A1 (VERSLUYS KILEY JAMES [US] ET AL) 18 January 2018 (2018-01-18) * the whole document * -----	8,12-14	
A	US 2018/045469 A1 (POLLARD BERWYN [GB]) 15 February 2018 (2018-02-15) * the whole document * -----	1-15	
A	EP 3 150 952 A1 (ALFA LAVAL CORP AB [SE]; ALFA LAVAL PACKINOX [FR]) 5 April 2017 (2017-04-05) * figures 5-8 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC) F28F F28D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	24 October 2018	Schindler, Martin

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 18 27 5099

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-10-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006032251 A1	16-02-2006	AU 2003269494 A1	04-05-2004
		EP 1549895 A1	06-07-2005
		US 2006032251 A1	16-02-2006
		WO 2004033978 A1	22-04-2004
EP 2474803 A2	11-07-2012	EP 2474803 A2	11-07-2012
		US 2012168112 A1	05-07-2012
US 2018015539 A1	18-01-2018	EP 3269474 A1	17-01-2018
		US 2018015539 A1	18-01-2018
US 2018045469 A1	15-02-2018	GB 2552801 A	14-02-2018
		US 2018045469 A1	15-02-2018
EP 3150952 A1	05-04-2017	CN 108139182 A	08-06-2018
		EP 3150952 A1	05-04-2017
		EP 3356757 A1	08-08-2018
		KR 20180061284 A	07-06-2018
		US 2018274865 A1	27-09-2018
		WO 2017055568 A1	06-04-2017

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 2474803 A **[0076] [0078]**
- US 2015260459 A **[0078]**