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(54) **PLUG CONNECTOR, PLUG CONNECTOR PART AND METHOD OF PRODUCING A PLUG CONNECTOR PART**

(57) The invention relates to a plug connector (100) comprising at least one plug connector part (70, 94) that comprises a foam structure (10) having a plurality of channels, cells and/or pores. Further, the invention relates to a plug connector part (70, 94) comprising at least one foam structure (10) having a plurality of channels, cells and/or pores. Moreover, the invention relates to a method of producing a plug connector part (70, 94), the method comprising a step of manufacturing a foam structure (10) having a plurality of channels, cells and/or pores.

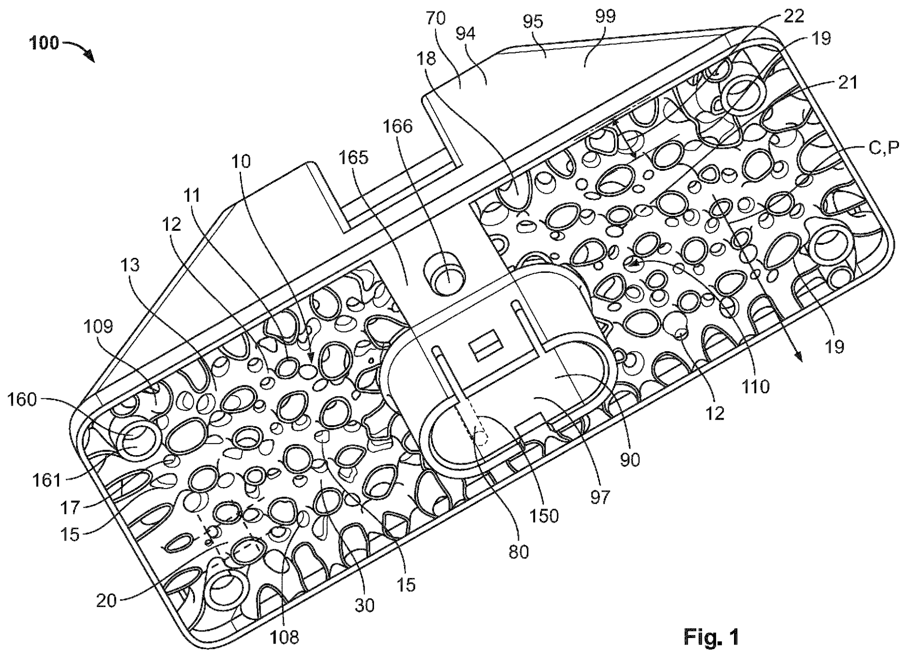

Fig. 1

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Description

[0001] The invention relates to a plug connector, a plug connector part, i.e. a part for or of a plug connector, and a method of producing a plug connector part.

[0002] In many applications, for example in aerospace applications, the weight of a plug connector is important. Conventionally, the weight of the plug connector can be reduced by reducing the thickness of walls of the plug connector. However, this is limited by the fact that sufficient mechanical stability has to be provided.

[0003] The object of the invention is to provide a plug connector that is light, but has sufficient stability.

[0004] According to the invention, this is achieved when at least one plug connector part comprises a foam structure having a plurality of channels, cells and/or pores.

[0005] The corresponding method comprises a step of manufacturing a plug connector part having a foam structure.

[0006] The foam structure requires less material than solutions with plane and rectangular elements. Due to the curved shape of the inner parts of the foam structure, connections between two elements can be shorter. The plug connector hence requires less material and is lighter.

[0007] The solution according to the invention can further be improved by the following further developments and advantageous embodiments, which are independent of each other and can be combined arbitrarily, as desired.

[0008] Plug connectors parts often comprise stabilizing structures for stabilizing a three-dimensional shape of the plug connector part or the plug connector. The foam structure can be at least a part of the stabilizing structure. Due to the advantageous configuration of the foam structure, the plug connector can be lighter while having the same stability as a plug connector having planar and rectangular sections only.

[0009] The foam structure can lie in an inner volume of a housing of the plug connector. In particular, the foam structure can lie entirely in the inner volume of the housing. The housing can be at least partially open in an unmounted state. The inner volume can be defined by an envelope of housing walls of the plug connector. The housing can comprise the foam structure. According to an advantageous embodiment, the foam structure is a support structure or a part of a support structure. The support structure can support an element by making a stable mechanical connection to a further, stable element that, for example, is attached or adapted to be attached to a rigid external structure. The foam structure can for example extend from at least one housing wall to a contact element receptacle adapted to receive at least one contact element. The contact element receptacle can thus be supported by the housing wall via the foam structure.

[0010] The foam structure can extend 360° around the contact element receptacle, in particular around a connection direction along which the plug connector is adapted to be connected to a mating device, such as a mating plug connector.

[0011] In an advantageous embodiment, the housing comprises mainly housing walls that are flat and/or curved in a single direction only. Preferably, the housing only consists of housing walls that are flat and/or curved in a single direction only, i.e. no other housing wall is present in the plug connector.

[0012] According to an additional or alternative advantageous embodiment, the foam structure is a fluid conduction structure or a part of a fluid conduction structure of the plug connector. The fluid conduction structure can be used for cooling or heating at least a part of the plug connector, for example for cooling at least one contact element or another heat source, for example an integrated circuit (IC), a sensor, a controller or other electric or electronic elements. The fluid conduction structure and/or the foam structure should be in thermal connection with the heat source. They can at least partially surround the heat source.

[0013] To allow a good force flow, the surface of wall sections of the foam structure is preferably continuously differentiable, possibly except for regions close to an envelope or a border, where it might be preferable for the surface to extend perpendicular to external structures bordering or lying next to the foam structure.

[0014] In a development that allows a further reduction of material and thus weight, the foam structure is part of at least two of the stabilizing structure, the support structure and the fluid conduction section.

[0015] The plug connector can comprise further elements, for example at least one male or female contact element (as a pin, socket and/or receptacle).

[0016] The plug connector part can, for example be a housing part that at least partially houses other parts or a base part to which further parts are mounted. The stabilizing structure, the support structure and/or the fluid conduction structure can be separate parts of the plug connector that can be attached to other parts or be integral with other parts.

[0017] In an advantageous development, the plug connector part is manufactured with an additive manufacturing method or method step (also referred to as 3D-printing), for example with selective melting of a metal or polymer powder, selective polymerization and/or hardening from a liquid with a light source (in particular a laser), or methods were material is applied via a movable nozzle.

[0018] In a development that allows the additive production by the layer-wise melting of fine-grained material, any point of a void of the foam structure is accessible from outside. This allows the complete removal of the fine-grained material after the production process. Accessible from outside here means that the point can be connected to an outside point with a continuous path, the path having sections that are straight, bent or curved. As in the rest of the document, the void is defined as the empty space lying within the envelope of the foam structure outside wall sections of the foam structure.

[0019] The expression "foam structure" should be understood as relating to a concrete physical structure (or body) rather than just the underlying abstract structure. The foam structure is a three-dimensional entity or object, the wall sections of which resemble in some embodiments an almost or quasi two-dimensional manifold in a three-dimensional space. The void between the wall sections can be seen as being a part of the foam structure. The foam structure is thus a foam body. A body can in particular be a unitary, monolithic structure.

[0020] The foam structure can be a unitary foam structure. In contrast to a foam structure comprising two or more parts, the unitary foam structure can be handled more easily.

[0021] In one development, the foam structure is an open foam structure having only open channels, cells and/or pores. This can allow a flow of a fluid.

[0022] According to a further development, the foam structure is a closed foam structure having only closed channels, cells and/or pores. This can prevent the ingress of dirt or water.

[0023] In a still further development, the foam structure has open and closed channels, cells and/or pores.

[0024] In a preferred embodiment enabling in particular the use as a fluid conduction structure, the foam structure comprises at least one open face having a total area comprising a first subarea and a second subarea, wherein each point of the void of the first subarea can be connected to a point of the void of the second subarea by a path running only through the void of the foam structure. Such a path does not leave the foam structure and does not intersect the envelope of the foam structure. This can enable a good flow of a fluid, like a gas or a liquid. The fluid can, for example, be used for cooling or heating at least a part of the plug connector. A flow of the fluid can be achieved by pressuring the fluid at an inlet and/or by sucking at an outlet and creating a pressure lower than the surrounding pressure, for example the atmospheric pressure.

[0025] The open face can be a part or a partial area of the envelope not covered by a wall or material. At the open face, the interior or channels of the foam structure are directly or indirectly accessible from outside.

[0026] Similarly, each point of the void of the second subarea can be connected to a point of the void of the first subarea by a path running only through the void of the foam structure. This can allow a good flow in the opposite direction.

[0027] Preferably, the open face contains the first subarea and the second subarea, i.e. the first subarea plus the second subarea make up the entire open face with no further subareas being present.

[0028] In a similar development, at least 70%, preferably at least 80%, especially at least 90% of the points of the first subarea can be connected to a point of the void in the second subarea by a path running only through the void of the foam structure. Again, this leads to a high flow rate of the fluid. Points that cannot be connected are points in wall sections of the foam structure and points in partially closed bubble sections. Partially closed bubble sections can, for example, be similar to a half sphere that is open at the first subarea. Preferably, no partially closed bubble sections can be found at the first subarea.

[0029] The preceding also applies to the second subarea, i.e. at least 70%, preferably at least 80%, especially at least 90% of the points of the second subarea can be connected to a point of the void in the first subarea by a path running through the void of the foam structure.

[0030] In a preferred embodiment, the total area is made up by at least a first open face and a second open face. The first open face is different from the second open face with no overlap between the two. They can be separated by a continuous border element, for example a wall or a line.

[0031] In one embodiment, the first subarea is located entirely within the first open face. Preferably, the first open face comprises only the first subarea. This can allow for an easy operation, as for example the first open face can easily be sealed and pressurised with the fluid.

[0032] Similarly, the second subarea can be located entirely within the second open face. Again, an easy operation is possible when the second open face comprises only the second subarea. If the second open face is used as an outlet, the fluid can be taken up by sealing the second open face. In this embodiment, the sealing can facilitate the creation of a low pressure for sucking the fluid through the foam structure.

[0033] In an embodiment that allows the use in different configurations, the total area comprises an alternative first subarea and an alternative second subarea in addition to the first subarea and the second subarea.

[0034] The alternative first subarea should be different from the first subarea. For example, an overlap of the two can be less than 90%, preferably less than 80%, more preferably less than 70%, in particular less than 60%, especially less than 50% of the first subarea and/or of the alternative first subarea.

[0035] The same applies for the alternative second subarea, i.e. the alternative second subarea should be different from the second subarea. For example, an overlap of the two can be less than 90%, preferably less than 80%, more preferably less than 70%, in particular less than 60%, especially less than 50% of the second subarea and/or of the alternative second subarea.

[0036] The plug connector can be configured such that in a first mounting configuration of the plug connector the first subarea is located entirely below the second subarea, and in a second mounting configuration of the plug connector at least a section of the alternative second subarea is located at least at the same height as at least a section of the alternative first subarea. Such a plug connector thus allows a cooling by convection in the first and the second mounting configuration. Air can be drawn in at the first subarea or the first alternative subarea, respectively. The warm and less dense air can then automatically exit the plug connector at the second subarea or the second alternative subarea, respectively. This can create a pressure gradient that automatically sucks in fresh air into the first subarea or first alternative subarea, respectively. The expression "below" here has to be understood as relative to the surface of earth or closer to the centre of gravity of earth. It is to be understood that the second mounting configuration is different from the first mounting configuration. The first and/or the second mounting configuration can be defined in official or company standard.

[0037] If in the second mounting configuration the alternative second subarea is at the same level as the alternative first subarea, the alternative second subarea is preferably located closer to a heat source than the alternative first subarea to achieve the described automatic exiting and creation of a pressure gradient.

[0038] In an alternative development, in the second mounting configuration, at least a section, preferably all, of the alternative second subarea is located higher than at least a section, preferably all, of the alternative first subarea. This allows an easy exiting of warmed up air and avoids, at least partially, that the warmed up air is sucked into the foam structure through the alternative first subarea. Rather, the warmed up air moves automatically away from the plug connector.

[0039] The first subarea, the second subarea, the alternative first subarea and the alternative second subarea can lie in a common plane.

[0040] In one development, a first orientation of the plug connector in the first mounting configuration is rotated at least 60° about a rotation axis parallel to a surface of earth relative to a second orientation of the plug connector in the second mounting configuration. The rotation axis is then perpendicular to a direction pointing away from a centre of gravity of earth, for example a surface normal. Preferably, the first orientation is rotated by 90° relative to the second orientation.

[0041] The rotation axis can be parallel to a connection direction, in particular a plugging direction, along which the plug connector is connected to or plugged into a mating device, in particular a mating plug connector.

[0042] In a different development, the rotation axis is perpendicular to the connection direction, or the plugging direction of the plug connector, respectively.

[0043] Preferred locations of the subareas can also be defined in a reference system of the plug connector. For example, in an advantageous development, the first subarea lies entirely in a first half-space of a separation plane, and the second subarea lies entirely in a second half-space of the separation plane, and wherein at least a part of the alternative first subarea lies in the second half-space. The second half-space is different from, in particular opposite to, the first half-space. In particular, the first half-space and the second half-space do not overlap. They rather are complementary and the combination of the two comprises the entire space.

[0044] Preferably, at least a part of the alternative second subarea lies in the first half-space.

[0045] The separation plane can be a symmetry plane of the housing or of an outer shape of the plug connector.

[0046] In another development, the first subarea and the second subarea can be separated from each other by a two-dimensional structure other than a plane. Again, the first subarea lies on one side of this two-dimensional structure and the second subarea lies on the other side of the two-dimensional structure. The alternative first subarea and/or the alternative second subarea can at least in parts extend at both sides. The two-dimensional structure can, for example, look like a bent or folded sheet of paper.

[0047] The first subarea, the second subarea, the alternative first subarea and/or the alternative second subarea can be understood as being abstract or virtual two-dimensional subparts of the at least one open face, which can be a rather concrete (quasi two-dimensional) physical element.

[0048] Each open face can be surrounded or limited by a closed border element in which material is present for a defined width.

[0049] The at least one open face can be a planar open face to allow an easy production or an easy mating to a mating device that has an at least partially planar mating section.

[0050] In the above configurations, the planar open face can be perpendicular to the surface of earth in the first mounting configuration, while it can be parallel to the surface of earth in the second mounting configuration, or vice versa.

[0051] In one development, in the first mounting configuration, the first subarea and the second subarea are located next to each other, and in the second mounting configuration, the alternative first subarea surrounds the alternative second subarea. In the first mounting configuration, the first subarea and the second subarea can be separated by a straight separation line or by an open bent separation line. In the second mounting configuration, the separation line between the alternative first subarea and the alternative second subarea can be closed, for example a closed bent separation line like a circle or a closed separation line comprising several straight sections, for example a polygon.

[0052] Preferably, the first subarea and the second subarea have basically the same size. The flow rate can then be better than with two differently sized subareas, in particular if the fluid has little or no compressibility. Similarly, the alternative first subarea and the alternative second subarea preferably have basically the same size.

[0053] To allow an easy supply or uptake of the fluid, the plug connector can comprise at least one fluid port. The fluid port can be adapted for the flow of a fluid, i.e. a gas or a liquid. The fluid port can be a standardized port to allow coupling to other standardised parts. Relevant parameters can be defined in official or company standards. The fluid port can lead to the foam structure. It can provide access to the foam structure for the fluid, in particular an open face of the foam structure. Through the open face, the void of the foam structure can be accessed. The fluid port can provide access to the first subarea or the second subarea. A cross section of the fluid port can comprise a geometric centre of the first or second subarea, respectively, to allow a good distribution of the fluid.

[0054] The fluid port can, at least in sections, be tubular and/or cylindrical to facilitate the flow of the fluid.

[0055] To allow an easy coupling, the fluid port preferably comprises at least one coupling section. The coupling section can be standardized, for example according to a national, an industry or a company standard.

[0056] In one development, the plug connector comprises only one fluid port. This fluid port can be used as an inlet for a preferably pressurized fluid, which can then exit through an open face, for example in the case of air or water.

[0057] The single fluid port may, in an alternative, be an outlet. A low pressure can be applied at the outlet in order to suck the fluid through the foam structure. The fluid can enter the foam structure at an open face.

[0058] Similar as for the first and the second subarea, each point of a void at an inlet cross section or an outlet cross section can be connected to a point of the outlet cross section or the inlet cross section, respectively, by a path leading through the void of the foam structure. The outlet cross section and the inlet cross section can each contain the entire fluid flow.

[0059] The foam structure can be configured to force a predefined fluid into a laminar flow up to a predefined laminar threshold pressure. This can result in a high flow rate and a high throughput of the fluid.

[0060] In addition or in an alternative, the foam structure can be configured to force a predefined fluid into a turbulent flow above a predefined turbulent threshold pressure. A result of this can be that the fluid is in the foam structure for a longer time and can then take up more heat in the case of cooling or release more heat if used for heating.

[0061] A shifting of the predefined laminar threshold pressure can, for example, be achieved by varying an allowed maximum distance between parts of the wall section, an allowed minimum radius of curvatures or by the addition of guiding wall sections. Such parameters or measures can be defined when a foam structure is created or optimized iteratively, for example with a computer program.

[0062] Similarly, the predefined turbulent threshold pressure can be influenced, for example by varying a defined minimum distance that at least one section has, or by varying a predefined maximum radius of curvature.

[0063] Examples of the predefined fluid are in particular air (as a gas or a liquid), water, nitrogen (as a gas or a liquid), or oil.

[0064] The laminar threshold pressure can be defined preferably as 2.0, 3.0, 5.0, or 10.0 bar.

[0065] Similarly, preferred values of the turbulent threshold pressure are 2.0, 3.0, 5.0, or 10.0 bar.

[0066] In each case, the value should be reduced by one bar to come approximately to the pressure above atmospheric pressure.

[0067] In a preferred development, the plug connector comprises at least two ports.

[0068] In one development, the plug connector can comprise one port as an inlet and one port as an outlet. This allows for example an integration into a cooling or heating circuit. When the fluid flows through the plug connector, it can take up or release heat. In another part of the cooling or heating circuit, the fluid can then actively or passively be cooled or heated and redirected to the plug connector.

[0069] In a further development, the plug connector comprises at least two fluid ports, at least two of the at least two fluid ports being configured as inlets. By this, two different fluids can be used, in particular one fluid in the form of a gas and one fluid in the form of a liquid. Depending on the cooling or heating requirements, a first fluid, a second fluid or both fluids can then be used.

[0070] According to a further development, the plug connector comprises at least two foam structures, the foam structures being separate from each other. The two foam structures can, for example, be separated by at least one continuous, non-permeable wall. Separate here can mean that the foam structures, in particular the two envelopes thereof, do not overlap. Such foam structures do not have a common space that is part of both structures. However, they can be nested, interwoven or interleaved. For example, at least one channel of one foam structure can run through the other foam structure, the at least one channel being limited by a continuous tunnel-like wall. At least one foam structure can surround at least one part of another foam structure. Preferably, each of the two or more foam structures surrounds at least a part of the other foam structure(s). Each of the foam structures can have elongated channels, that for example resemble hoses or tubes, the channels of the at least two structures preferably being interwoven or braided.

[0071] The channels of different foam structures can in some sections run next to each other, for example in an alternating manner, and in other sections run perpendicular to each other.

[0072] The channels of different foam structures can have similar effective cross sections and/or physical cross sections. Effective cross section should be understood as relating to a certain flow rate that is possible from one end of the channel to another end of the channel.

[0073] In an alternative or in addition, the effective cross sections and/or physical cross sections of different foam structures can be different, for example if different fluids are to be used in the different foam structures.

[0074] The two foam structures can be configured or adapted to be used with different cooling mechanisms and/or different flow states (laminar vs. turbulent). For example, one foam structure can be configured for free, passive convection cooling and another foam structure can be configured for forced, active cooling. The two foam structures can be configured for a two-step cooling, a first foam structure being configured for taking up heat from a heat source and transferring it to a second foam structure, which in turn transfers the heat to an external element or circuit. The first foam structure may for example be located next to the heat source, while the second foam structure may be arranged away from the heat source, but next to an external element. The first foam structure may be closed, i.e. only allow a circulation of a fluid within the first foam structure. The circulation can be driven automatically, for example by a heat or density gradient within the fluid. The second foam structure can be open and for example have an inlet and an outlet were the fluid can enter and leave the second foam structure. The first and the second foam structure can be adapted or configured for an optimum of heat transfer between them, for example by maximizing the thermal interface area as in a heat exchanger. This can for instance be achieved by positioning sections having many small channels next to each other. Such a thermal transfer optimization can also be used if only one foam structure is present, for example in an parts where heat is supposed to be transferred from the heat source to the fluid in the foam structure or away from the fluid to an external element.

[0075] In one development, the at least two foam structures are associated with the same heat source to allow an adaptive cooling, for example with different flow rates or different fluids. As in the rest of the document, similar or the same considerations apply of course if instead of cooling, the foam structures are used for heating, or if one foam structure is used for heating and one foam structure is used for cooling.

[0076] In this context, heat source means an element that produces heat during operation, in particular as a side effect. For example, at least one contact element of an electrical plug connector can produce heat if a high current or high power runs through it, as is typically the case when charging electric vehicles. The term high is relative in this case and depends on the size, geometry and surrounding of the contact element. Heat should in particular relate to the temperature, and can mean that the element would be warmer than the rest of the plug connector or a surrounding area by at least 5 K, 10 K, or 20 K if not cooled, or which has such a temperature although being cooled. Other examples of heat sources include an integrated circuit (IC), a sensor, a controller or other electric or electronic components.

[0077] In another development, the plug connector comprises at least two heat sources, wherein each heat source is associated with at least one foam structure different from the foam structures associated with the other heat sources. This allows a selective and efficient cooling of the heat sources.

[0078] The two different foam structures can be parts of separate cooling circuits or be parts of the same cooling circuit and be configured in parallel or in series in this single cooling circuit. In particular, in the latter case, a connection between the two foam structures can be part of the plug connector, especially a part of the housing.

[0079] The solution according to the invention allows the use of less material than for a plug connector produced with other methods, in particular a conventional moulding method resulting in mainly straight or planar faces, while maintaining the same mechanical strength.

[0080] Advantageously, the volume of the void can be at least 80%, preferably at least 90%, especially at least 95% of the volume of the foam structure. The volume is defined as the volume enclosed by the envelope of the foam structure. The envelope can be defined as the surface enclosing the foam structure. It can be in one example be determined as the border surface of the foam structure with a large, preferably infinitely large sphere or an extended flat element touching the foam structure. The dimensions of the sphere of the extended flat element can be multiples of a spacing between wall sections of the foam structure.

[0081] Similarly, the volume of the wall section of the foam structure can be less than 20%, preferably less than 10%, especially less than 5% of the volume of the foam structure.

[0082] Moreover, a ratio of the volume of the void to the volume of the wall section is at least 4, preferably at least 9, especially at least 19.

[0083] In particular, the wall thickness of the wall section of the foam structure can be lower than the straight and rectangular wall sections that can be found in other parts of the plug connector. According to a preferred development, an average wall thickness of the wall section is less than 95%, preferably less than 90%, more preferred less than 80%, especially less than 70% of the minimum thickness of the housing walls. Moreover, a maximum wall thickness of the wall section, in particular in a core area, is less than 95%, preferably less than 90%, more preferred less than 80%, especially less than 70% of the minimum thickness of the housing walls.

[0084] In a preferred development, the foam structure is irregular or asymmetrical. It can in particular lack any mirror symmetry or any translational symmetry. In such a development, vibrations to which the plug connector is subjected result in vibrations in the plug connector with a lower amplitude than would be the case if a symmetry were present, as the vibrations are reflected to a lower degree and rather dispersed in the plug connector. Such a plug connector can thus have a better vibration performance.

[0085] To achieve a good force distribution and to facilitate printing, at least in a core area, the mean curvature of the foam structure can be substantially zero. The mean curvature can relate to the curvature at central parts of the wall section being located centrally between two surfaces of wall sections or two points on the surface of the wall section.

[0086] The core area can be defined as an area that is spaced at a defined spacing length from the envelope. The spacing length in turn can be defined as a fraction of a dimensional value of the structure, e.g. an x-, y- or z-extension, a longest or shortest diameter value, or a mean diameter of the foam structure. The fraction can be 30%, preferably 20%, especially 10%. In an alternative, the spacing length can have a fixed value. Outside the core area, the mean curvature can be different from zero in order to allow a good force flow to other, preferably straight or planar parts of the plug connector.

[0087] In one development, the plug connector is an electrical plug connector. Such an electrical plug connector can comprise at least one contact element, which can be the heat source. The plug connector can in particular be a high current or high power plug connector.

[0088] In other developments, the plug connector could be an optical plug connector (for optical fibres) or a plug connector for transmitting a fluid, for example pressurized air or liquid.

[0089] For a lightweight construction, the foam structure can be made from a plastic, in particular a plastic material. The plastic can comprise additional elements such as metal parts or fibres to allow a good heat transport or to improve mechanical stability.

[0090] In a further development, the foam structure can be made from a metal or at least comprise a metal. This can result in a good thermal conductivity.

[0091] The foam structure can be at least one of a 3D minimal surface structure, an adaptive density minimal surface structure (ADMS), a preferably continuously and/or doubly curved structure, a sponge-like structure, a sponge-shape structure, a spongeoid structure (being similar to but different from a sponge, in particular similar relating to the shape) or a biomimetic structure. The foam structure can be generally isotropic.

[0092] The wall sections of the foam structure can form a single continuous wall. In one development, no bifurcations are present in the wall sections, for example in order to optimize the flow of the fluid.

[0093] According to one development, the foam structure is edgeless outside open faces, that means outside the areas of the envelope where the void is accessible, the foam structure only exposes surfaces of the wall sections but no edge going from one side of the wall section to the opposite side of the wall section. The wall sections can have no holes going through them.

[0094] The envelope of the foam structure can be closed at least 70 %, preferably at least 80 %, especially at least 90 %, i.e. open faces make up at most 30 %, 20 % or 10 %, respectively.

[0095] The thickness of the wall sections can vary by a maximum value. In one development, the lowest thickness must not be less than 50 %, preferably at least 70 % of the highest thickness, especially at least 90 %, at least for the parts of the wall sections being away more than a defined amount from the envelope, for example at least 5 times an average thickness away from the envelope. If a comparable strength is to be achieved, a higher number of thinner walls can be present per volume.

[0096] Channels can be open at two ends. Pores can be closed or comprise one or more openings. Cells can be closed or open. Cavities can be closed or open. Closed means that in inner empty volume is present that is enclosed entirely with no openings leading thereto.

[0097] The term plug connector part refers to a part (or similar a component or a piece) of a plug connector that is separate from other parts (or components or pieces) of the connector. The plug connector can comprise or consist of only one part, except for contact elements.

[0098] The solution according to the invention can of course also be applied for other connectors that are not plug connectors, for example connectors where a connection is established by positioning a contact element or a guiding element for the relevant entity next to or in contact with a mating contact element or a mating connection element. An example would be an electrical connector having a plane contact element face that is pressed against a plane face of a mating contact element.

[0099] According to a further aspect, a method of producing a plug connector comprises a step of iteratively optimizing a foam structure for at least one physical parameter. The step can be performed by a computer.

[0100] The at least one parameter preferably comprises at least one of a flow speed of a fluid, a fluid throughput, a heat uptake of a fluid during a pass through, mechanical stability, weight, a laminar threshold pressure, or a turbulent threshold pressure.

[0101] Possible boundary conditions for the optimisation can be a shape of the housing, a required minimal flow rate or a required mechanical stability.

[0102] Some or all of the method steps may be executed by (or using) a hardware apparatus, such as, for example, a processor, a microprocessor, a programmable computer or an electronic circuit. In some embodiments, one or more of the most important method steps may be executed by such an apparatus.

[0103] Depending on certain implementation requirements, embodiments of the invention can be implemented in hardware or in software. The implementation can be performed using a non-transitory storage medium such as a digital storage medium, for example a floppy disc, a DVD, a Blu-Ray, a CD, a ROM, a PROM, and EPROM, an EEPROM or a FLASH memory, having electronically readable control signals stored thereon, which cooperate (or are capable of cooperating) with a programmable computer system such that the respective method is performed. Therefore, the digital storage medium may be computer readable.

[0104] Some embodiments according to the invention comprise a data carrier having electronically readable control signals, which are capable of cooperating with a programmable computer system, such that one of the methods described herein is performed.

[0105] Generally, embodiments of the present invention can be implemented as a computer program product with a program code, the program code being operative for performing one of the methods when the computer program product runs on a computer. The program code may, for example, be stored on a machine-readable carrier.

[0106] Other embodiments comprise the computer program for performing one of the methods described herein, stored on a machine-readable carrier.

[0107] In other words, an embodiment of the present invention is, therefore, a computer program having a program code for performing one of the methods described herein, when the computer program runs on a computer.

[0108] A further embodiment of the present invention is, therefore, a storage medium (or a data carrier, or a computer-readable medium) comprising, stored thereon, the computer program for performing one of the methods described herein when it is performed by a processor. The data carrier, the digital storage medium or the recorded medium are typically tangible and/or non-transitionary. A further embodiment of the present invention is an apparatus as described herein comprising a processor and the storage medium.

[0109] A further embodiment of the invention is, therefore, a data stream or a sequence of signals representing the computer program for performing one of the methods described herein. The data stream or the sequence of signals may, for example, be configured to be transferred via a data communication connection, for example via the internet.

[0110] A further embodiment comprises a processing means, for example a computer or a programmable logic device, configured to, or adapted to, perform one of the methods described herein.

[0111] A further embodiment comprises a computer having installed thereon the computer program for performing one of the methods described herein.

[0112] A further embodiment according to the invention comprises an apparatus or a system configured to transfer (for example electronically or optically) a computer program for performing one of the methods described herein to a receiver. The receiver may, for example, be a computer, a mobile device, a memory device or the like. The apparatus or system may, for example, comprise a file server for transferring the computer program to the receiver.

[0113] In some embodiments, a programmable logic device (for example a field programmable gate array) may be used to perform some or all of the functionalities of the methods described herein. In some embodiments, a field programmable gate array may cooperate with a microprocessor in order to perform one of the methods described herein. Generally, the methods are preferably performed by any hardware apparatus.

[0114] The invention will now be described in greater detail and in an exemplary manner using advantageous embodiments and with reference to the drawings. The described embodiments are, however, only possible configurations in which the individual features as described above can be provided independently of one another or can be omitted.

[0115] In the figures:

Fig. 1 shows a schematic perspective view of a first embodiment of a plug connector;

Fig. 2 shows a schematic perspective view of a second embodiment of a plug connector;

Fig. 3 shows a schematic front view of the second embodiment of a plug connector;

Fig. 4 shows a schematic cross sectional view of a third embodiment of a plug connector in a first mounting configuration;

Fig. 5 shows a schematic cross sectional view of the third embodiment of a plug connector in a second mounting configuration;

Fig. 6 shows a schematic cross sectional view of a fourth embodiment of a plug connector; and

Fig. 7 shows a schematic cross sectional view of a fifth embodiment of a plug connector.

[0116] In the figures, different embodiments of plug connectors 100 are depicted. The depicted embodiments show electrical plug connectors 100 that comprise at least one contact element 80 for contacting a mating plug connector (not depicted) along a connection direction C. In particular, the plug connector 100 can be plugged together with a mating plug connector along a plugging direction P, which is parallel to the connection section C.

[0117] Each of the plug connectors 100 comprises a foam structure 10 located in an inner volume 98 of a housing 94 of the plug connector 100. The foam structure 10 is a part of the housing 94. The housing 94 further comprises housing walls 95 at an outside. The housing walls 95 consist mainly of planar sections or curved sections that are bent along a single direction only. One side of the housing 94 is an open side 93. The inner sides of the housing walls 95 and the open side 93 define an envelope 99 in which the foam structure 10 lies.

[0118] The housing 94 is a plug connector part 70. In the depicted examples, the plug connector 100 comprises, except for the contact elements 80, only one plug connector part 70, namely the housing 94.

[0119] The foam structure 10 stabilizes the three-dimensional shape of the plug connector 100. Forces that try to deform the plug connector 100 are taken up by the foam structure 10. The foam structures 10 are thus part of a stabilizing structure 109.

[0120] Further, the foam structures 10 act as support structures 110 that support the contact element receptacle 90 in the plug connector 100. The foam structures 10 extend from walls 97 of the contact receptacles 90 to housing walls 95 of the housing 94.

[0121] In addition, the foam structures 10 are parts of a fluid conduction structure 108 allowing the flow of a fluid, for example a cooling agent.

[0122] The foam structures 10 comprise channels 15, pores 16, cavities 17 and cells 18. The depicted foam structures 10 are basically open. In other embodiments, the foam structure 10 can be at least partially or completely closed, for example if closed cavities 17 or closed cells 18 are used.

[0123] The contact elements 80 are located in contact element receptacles 90 located centrally in the plug connectors 100. In particular, when high currents or high power is transferred with the plug connectors 100, the contact elements 80 warm up and act as heat sources 150. The depicted open foam structures 10 allow the flow of a fluid to cool the heat sources 150. Fluids can be gases or liquids. In some examples, for example the ones of Figs. 1 to 5, the cooling can be passive by free convection of air. In other examples, for example the ones of Figs. 6 and 7, the fluid can be pressed into or sucked out of the foam structure 10, resulting in an active cooling.

[0124] The depicted foam structures 10 are irregular and do not have any symmetries, in particular no translational or mirror symmetries, in order to improve the vibration performance. The foam structures 10 comprise wall sections 11 and a void 12 between the wall sections 11. The void 12 is the free space between the wall sections 11.

[0125] Advantageously, the wall sections 11 form a single wall. Such a wall can be free of bifurcations. The wall sections 11 can be flat, basically two-dimensional wall sections 11. The wall sections 11 can be seen as basically two-dimensional manifold (having, however, a certain thickness) within the three-dimensional inner volume 98. The wall sections 11 are in large parts curved. Central parts of the wall sections 11 and surfaces 13 of the wall sections 11 are continuously differentiable to allow a good force flow.

[0126] In a core section 21 of the foam structure 10, the mean curvature of the wall sections 11 and of the surfaces 13 of the wall sections 11 is basically zero. The core section 21 is defined as being spaced from the envelope 99 at least by a spacing length 22. The spacing length 22 can depend on the position within the foam structure 10. It can be longer or shorter on an open side 93 than in other parts. Outside the core section 21, the mean curvature can be different from zero, in particular in order to achieve a good force transmitting connection to the housing walls 95.

[0127] The shape of the foam structure 10 can be optimized by a computer program or an algorithm. Several physical parameters can be considered in such an optimization process, for example a desired mechanical stability, a desired flow rate, a desired flow state (laminar vs. turbulent), a weight. Certain parameters, for example a required stability, can be boundary conditions for the optimization.

[0128] The foam structures 10 can in particular be created by an additive manufacturing process like 3-D printing. In one process, fine-grained material is melted selectively. In order to allow the removal of the fine-grained material, any point of a void 12 of the foam structure 10 is accessible from outside. The accessibility can require openings that have certain sizes, for example multiples of a grain size of the material.

[0129] In a further process, material could be added from a nozzle. Furthermore, the foam structure 10 could be created by a chemical process in which gas is produced in a liquid material which then solidifies. In other embodiments, the additive manufacturing includes polymerization or hardening from a fluid, for example with a laser.

[0130] The foam structures 10 extend 360° around the contact element receptacles 90 around the connection direction C to achieve an efficient cooling and to provide sufficient support.

[0131] The plug connectors 100 further have mounting sections 160 in the form of holes 161 that allows a fixation to a mating structure or an external element for example with a screw.

[0132] In Fig. 1, a further support element 165 is depicted that extends from the housing wall 95 to the contact element receptacle 90. A keying feature 166 protrudes from the further support element 165 to allow a mating only in a desired rotational orientation.

[0133] As can for example be seen in Figs. 1 and 2, the foam structures 10 comprise open faces 30 at which the voids 12 of the foam structures 10 are accessible. The open face 30 is in each case part of the envelope 20 of the foam structure 10. The envelope 20 further runs around the inside of the housing walls 95 of the housing 94 and the walls 97 of the contact element receptacle 90. The depicted open faces 30 are planar, but could have other shapes, for example shapes that are bent in one or two directions.

[0134] In Fig. 3. through-holes 89 for contact elements 80 are visible.

[0135] In Figs. 4 and 5, an embodiment of a plug connector 100 having a foam structure 10 is depicted in two different mounting configurations 61, 62. In the first mounting configuration 61 depicted in Fig. 4, the plug connector 10 has a first orientation 71 relative to a surface normal 69 of earth. In a second mounting configuration 62 depicted in Fig. 5, the plug connector 10 has a second orientation 72 relative to the surface normal 69. The two orientations 71, 72 are rotated relative to each other around a rotation axis 65 that is perpendicular to the surface normal 69.

[0136] In Fig. 4, a first subarea 41 of the open face 30 lies entirely below a second subarea 42 of the open face 30. The first subarea 41 and the second subarea 42 make up the entire open face 30 and have approximately the same surface area to allow a good flow of fluid. Preferably, any point 41X of a void 41A of the first subarea 41 can be connected to a point 42X of a void 42A of the second subarea 42 by a path 45 that runs entirely through the void 12 of the foam structure 10. The path 45 does not intersect the envelope 20. This allows a good circulation of the fluid.

[0137] In turn, any point 42X of a void 42A of the second subarea 42 can be connected to a point 41X of a void 41A of the first subarea 41 by a path 45 that runs entirely through the void 12 of the foam structure 10. However, in reality, the subareas 41, 42 may also comprise areas 41C that relate to partially closed bubble sections (or in other words: pores that are open to one side only, namely the first subarea 41. Such partially closed bubble sections may be necessary for achieving a certain stability. Thus, only a certain percentage of the subareas 41, 42 can be connected to the other subarea 42, 41 by a continuous path 45 running through the foam structure 10. The percentages are further reduced by taking into account the areas 41B, 42B relating to wall sections 11 of the foam structure 10.

[0138] In the first mounting configuration 61 shown in Fig. 4, heat is generated by the contact elements (not depicted in Fig. 4) located in the contact element receptacle 90. The heat warms up air located in the void 12 the foam structure 10. The warm and less dense air then leaves the plug connector through the second subarea 42 in an upwards direction. The second subarea 42 thus acts as an outlet 135. The resulting lower pressure in the void 12 then sucks in fresh air through the first subarea 41 which acts as an inlet 130. The heat sources 150 in the plug connector 100 are hence automatically passively cooled by the resulting flow 170 of the fluid. In this first mounting configuration 61, the first subarea 41 lies completely in a first half space 46 of a separation plane 49 and the second subarea 42 lies completely in the second half space 47 of the separation plane 49, the second half space 47 being disjunct and complementary to the first half space 46. A separation line 48 between the first subarea 41 and the second subarea 42 in this configuration 61 is a straight line.

[0139] In the second mounting configuration 62 shown in Fig. 5, the plug connector 100 is arranged horizontally with the open face 30 lying horizontally, i.e. perpendicular to the surface normal 69. In this case, a passive cooling by convection is also possible. The flow 170 of the fluid is however different. An alternative first subarea 141 surrounds an alternative second subarea 142, both being part of the open face 30. The alternative second subarea 142 surrounds the contact element receptacle 90 and is closer to the contact element receptacle 90 than the alternative first subarea 141. Again, the contact elements 80 (not depicted in Fig. 5) act as heat sources 150 that warm up air next to it. The warm air leaves the foam structure 10 through the alternative second subarea 142. Fresh air is sucked in further away from the heat source 150 through the alternative first subarea 141. To allow such a flow 170 of the fluid, a high percentage, preferably all points 141X in a void 141A of the altemative first subarea 141 can be connected to a point 142X in a void 142A of the alternative second subarea 142 by a path 45 running through the void 12 of the foam structure 10 only, and vice versa. A separation line 48 between the alternative first subarea 141 and the alternative second subarea 142 in this example is a closed ring. The alternative first subarea 141 and the alternative second subarea 142 lie in a common plane and at the same height.

[0140] In this second mounting configuration 62, the alternative first subarea 141 lies partially in the first half space 46 and partially the second half space 47. Similarly, the alternative second subarea 142 lies partially in the first half space 46 and partially in the second half space 47. A separation line 48 between the alternative first subarea 141 and the alternative second subarea 142 in this example is a closed ring.

[0141] In the embodiments of Figs. 1 to 5, the total area is made up by a single open face 30. The total area can however comprise more than one open face 30, for example a first open face 31 and a second open face 32, as is shown in Fig. 6, or four open faces as depicted in Fig. 7.

[0142] In the embodiment of Fig. 6, the first open face 30, 31 comprises only the first subarea 41 through which the fluid flows into the foam structure 10. The second open face 30, 32 comprises only the second subarea 42 through which the fluid leaves the foam structure 10. The open faces 30, 31, 32 are in each case accessible through a fluid port 120, at least for the fluid. The first fluid port 120, 121 acts as an inlet 130. The entire fluid flow 170 runs through an inlet cross section 134 of the inlet 130. The second fluid port 120, 122 acts as an outlet 135. The entire fluid flow 170 runs through an outlet cross section 139 of the outlet 135.

[0143] The fluid ports 120, 121, 122 are tubular or cylindrical. Each of them comprises a coupling section 129 adapted to mate with a coupling section of a fluid supply. The coupling section 129 can standardized.

[0144] In the embodiment of Fig. 7, the plug connector 100 comprises two foam structures 10 that are separated by a wall 29. The wall 29 prevents the flow of fluid from one foam structure 10 to the other foam structure 10 and vice versa.

[0145] A first foam structure 10, 111 is associated with a first heat source 150, 151 in the form of a first contact element 80, 81 that is connected to a contact element 80 of a mating plug connector (only the contact elements 80 of the mating plug connector are depicted). The second foam structure 10, 112 is associated with a second heat source 150, 152 embodied by the second contact element 80, 82. This allows selective cooling of each of the heat sources 150, 151, 152.

[0146] The plug connector 100 of Fig. 7 comprises four fluid ports 120, a first fluid port 121 and a third fluid port serving as inlets 130 and a second fluid port 122 and a fourth fluid port 124 acting as outlets 135 for the fluids, which both work as cooling media.

[0147] The contact elements 80 of the mating plug connector are connected to cables 180 for transmitting current.

[0148] The foam structures 10 can be configured to force a predefined fluid into a laminar flow up to a predefined laminar threshold pressure. This can for example be achieved if the spacing 119 between parts of the wall sections 11 is nowhere bigger than a certain value or if the surface 13 of the wall section 11 only has radii of curvature bigger than a certain value.

[0149] Further, the foam structures 10 can be configured to force a predefined fluid into a turbulent flow above a predefined turbulent threshold pressure. To achieve this, the void 12 can have spaces where the spacing 119 is bigger than a threshold value or at least one section having a radius of curvature lower than a threshold value.

[0150] The depicted foam structures 10 are edgeless outside the open faces 30, that means outside the areas of the envelope 20 where the void 12 is accessible, the foam structure 10 only exposes surfaces 13 of the wall sections 11 but no edge 19 going from one side of the wall section 11 to the opposite side of the wall section 11. The wall sections 11 can have no holes going through them in this area. At the open faces 30, such edges 19 can be present. They relate to the areas 41C, 42C, 41C and 142C of the first or the second subarea 41, 42 and the alternative first and second subareas 141, 142, respectively.

[0151] The envelope 20 of the foam structure 10 can be closed at least 70 %, preferably at least 80 %, especially at least 90 %, i.e. open faces make up at most 30 %, 20 % or 10 %, as can be seen in the embodiments of Fig. 5 and 6.

[0152] In each of the embodiments, the thicknesses 118 of the wall sections 11 varies only little, preferably by a maximum value, for example approx. +/- 30 %, preferably approx. +/- 20 %, especially approx. +/- 10 %, of the average thickness. To compensate for thinner wall sections, the number of wall sections 12 per volume can be increased in a certain part space to maintain the strength.

[0153] The depicted solutions allow a reduction of the weight of the plug connector 100 relative to other solutions in which the stabilizing structure 109 or the support structure 110 comprise straight sections, possibly with sharp angles. This is at least partially due to the fact that a thickness 118 of the wall sections 11 can on average be lower than a thickness of wall sections of the previous solutions and for example a thickness 96 of housing walls 95 or the wall 97 of the contact element receptacle 90.

[0154] The foam structures 10, in particular the wall sections 11 of the foam structures 10 can be made from plastic, in particular a plastic material, or a metal.

REFERENCE NUMERALS

[0155]

10	foam structure
11	wall section
12	void of foam structure
13	surface of wall section
15	channel
16	pore
17	cavity
18	cell
19	edge
20	envelope of foam structure
21	core section
22	spacing length
29	wall between two foam structures
30	open face
31	first open face
32	second open face
41	first subarea
41A	void of first subarea
41B	areas of the wall section
41C	area of partially closed bubble section
41X	point
42	second subarea
42A	void of second subarea
42B	areas of the wall section
42X	point
45	path
46	first half-space
47	second half-space
48	separation line
49	separation plane
51	alternative first subarea
52	alternative second subarea
61	first mounting configuration
62	second mounting configuration
65	rotation axis
69	surface normal
70	plug connector part
71	first orientation
72	second orientation
80	contact element
81	first contact element
82	second contact element
89	through hole
90	contact element receptacle
91	first contact element receptacle
92	second contact element receptacle
93	open side
94	housing
95	housing wall
96	thickness housing wall
97	wall of contact receptacle
98	inner volume
99	envelope housing walls
100	plug connector
101	unmounted state
108	fluid conduction structure
109	stabilizing structure
110	support structure
111	first foam structure
112	second foam structure

118 thickness of wall section
119 spacing between parts of wall sections
120 fluid port
121 first fluid port
122 second fluid port
123 third fluid port
124 fourth fluid port
129 coupling section
130 inlet
131 first inlet
132 second inlet
134 inlet cross section
135 outlet
136 first outlet
137 second inlet
139 outlet cross section
141 alternative first subarea
141A void of alternative first subarea
141B areas of the wall section
141C area of partially closed bubble section
142X point
142 alternative second subarea
142A void of alternative first subarea
142B areas of the wall section
142X point
145 path
150 heat source
151 first heat source
152 second heat source
160 mounting section
161 hole
165 further support element
166 keying feature
170 fluid flow
180 cable
C connection direction
P plugging direction

Claims

1. Plug connector (100), in particular an electrical plug connector (100), comprising at least one plug connector part (70, 94) that comprises a foam structure (10) having a plurality of channels, cells and/or pores.

2. Plug connector (100) according to claim 1, wherein any point of a void (12) of the foam structure (10) is accessible from outside.

3. Plug connector (100) according to claim 1 or 2, wherein the foam structure (10) comprises at least one open face (30) having a total area comprising a first subarea (41) and a second subarea (42), wherein each point (41X) of a void (41A) of the first subarea (41) can be connected to a point (42X) of a void (42A) of the second subarea (42) by a path (45) running only through the void (12) of the foam structure (10).

4. Plug connector (100) according to claim 3, wherein each point (42X) of the void (42A) of the second subarea (42) can be connected to a point (41X) of the void (41A) of the first subarea (41) by a path (45) running through the void (12) of the foam structure (10).

5. Plug connector (100) according to claim 3 or 4, wherein the total area is made up by at least a first open face (30, 31) and a second open face (30, 32).

6. Plug connector (100) according to any one of claims 3 to 5, wherein the total area comprises an alternative first subarea (141) and an alternative second subarea (142).

7. Plug connector (100) according to claim 6, wherein the first subarea (41) lies entirely in a first half-space (46) of a separation plane (49) and the second subarea (42) lies entirely in a second half-space (47) of the separation plane (49), and wherein at least a part of the alternative first subarea (141) lies in the second half-space (47).

8. Plug connector (100) according to any one of claims 1 to 7, wherein the plug connector (100) comprises at least one fluid port (120) adapted to provide access to an open face (30) of the foam structure (10) for a fluid.

9. Plug connector (100) according to any one of claims 1 to 8, wherein the plug connector (100) comprises at least two foam structures (10, 111, 112), the foam structures (10, 111, 112) being separate from each other.

10. Plug connector (100) according to claim 9, wherein at least two of the at least two separate foam structures (10) are interwoven, interleaved and/or nested.

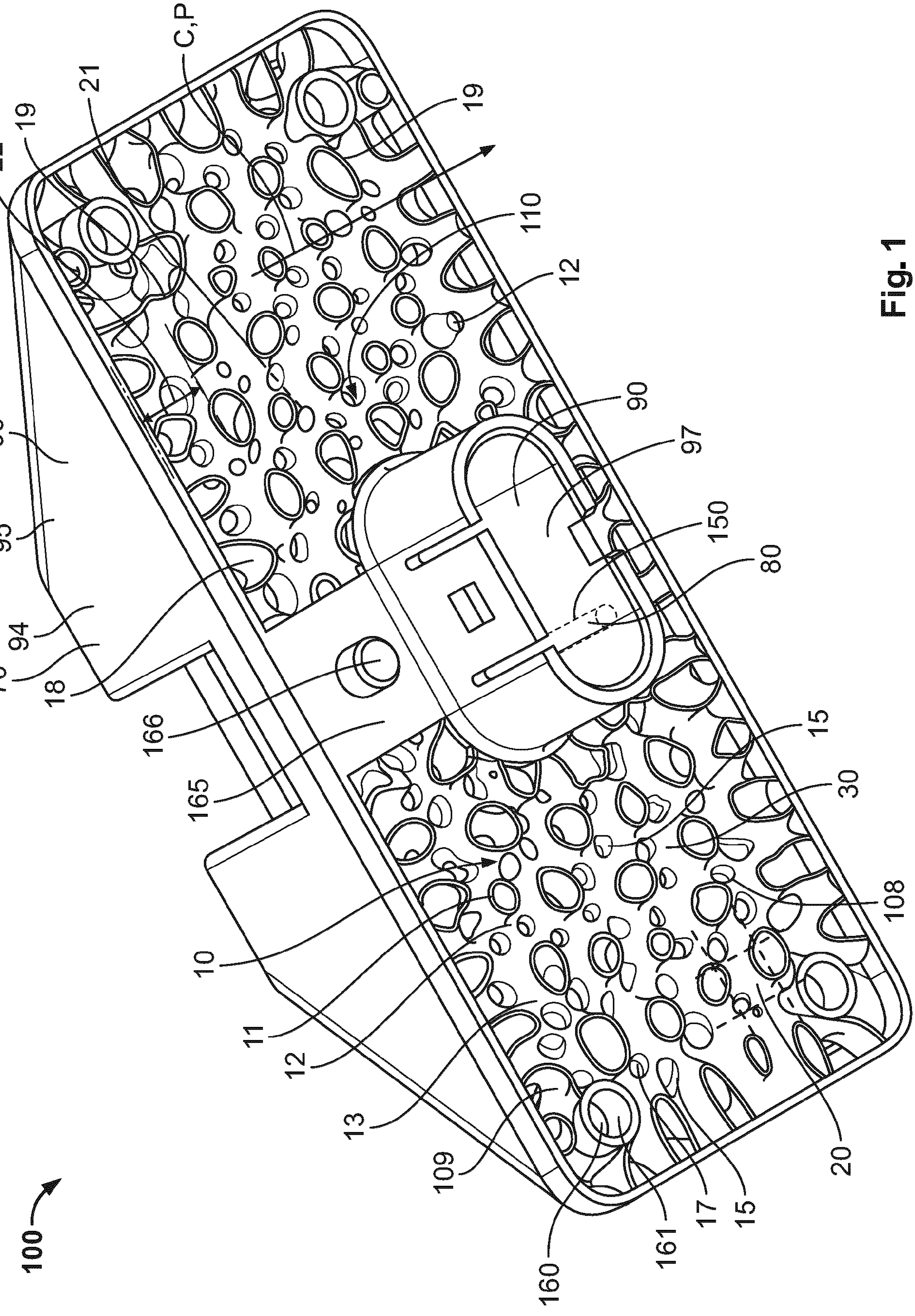
11. Plug connector (100) according to any one of claims 9 or 10, wherein the plug connector (100) comprises at least two heat sources (150, 151, 152), wherein each heat source (150, 151, 152) is associated with at least one foam structure (10, 111) different from the foam structures (10, 112) associated with the other heat sources (150, 152, 151).

12. Plug connector (100) according to any one of claims 1 to 11, wherein the foam structure (10) is at least a part of a fluid conduction structure (108), a stabilizing structure (109) and/or a support structure (110).

13. Plug connector part (70, 94) comprising at least one foam structure (10) having a plurality of channels, cells and/or pores.

14. Method of producing a plug connector part (70, 94), the method comprising a step of manufacturing a foam structure (10) having a plurality of channels, cells and/or pores.

15. Method of producing a plug connector part (70, 94), the method comprising a step of iteratively optimizing a foam structure (10) for at least one physical parameter.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C,P
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18
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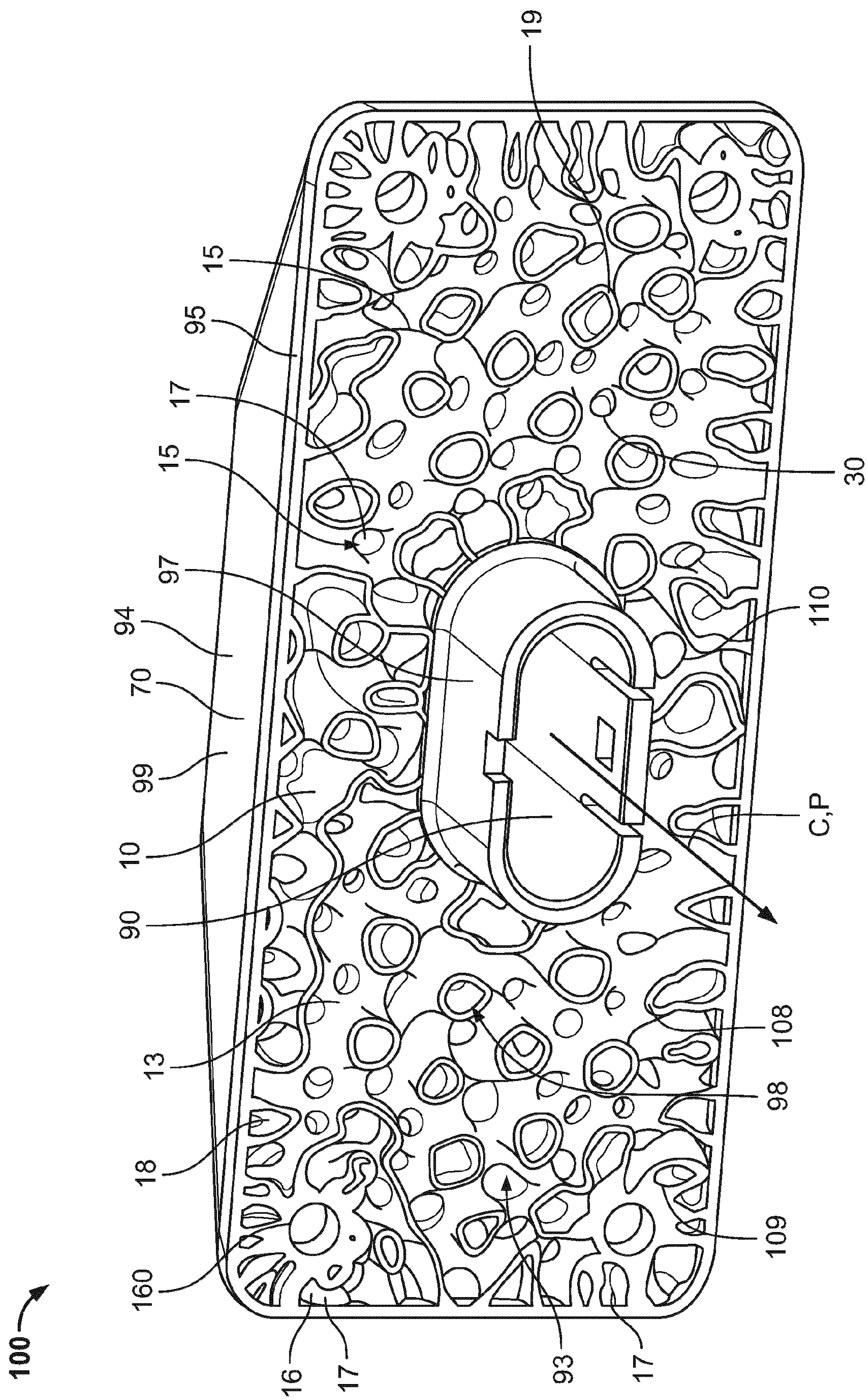
Fig. 1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C,P
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30

Fig. 2

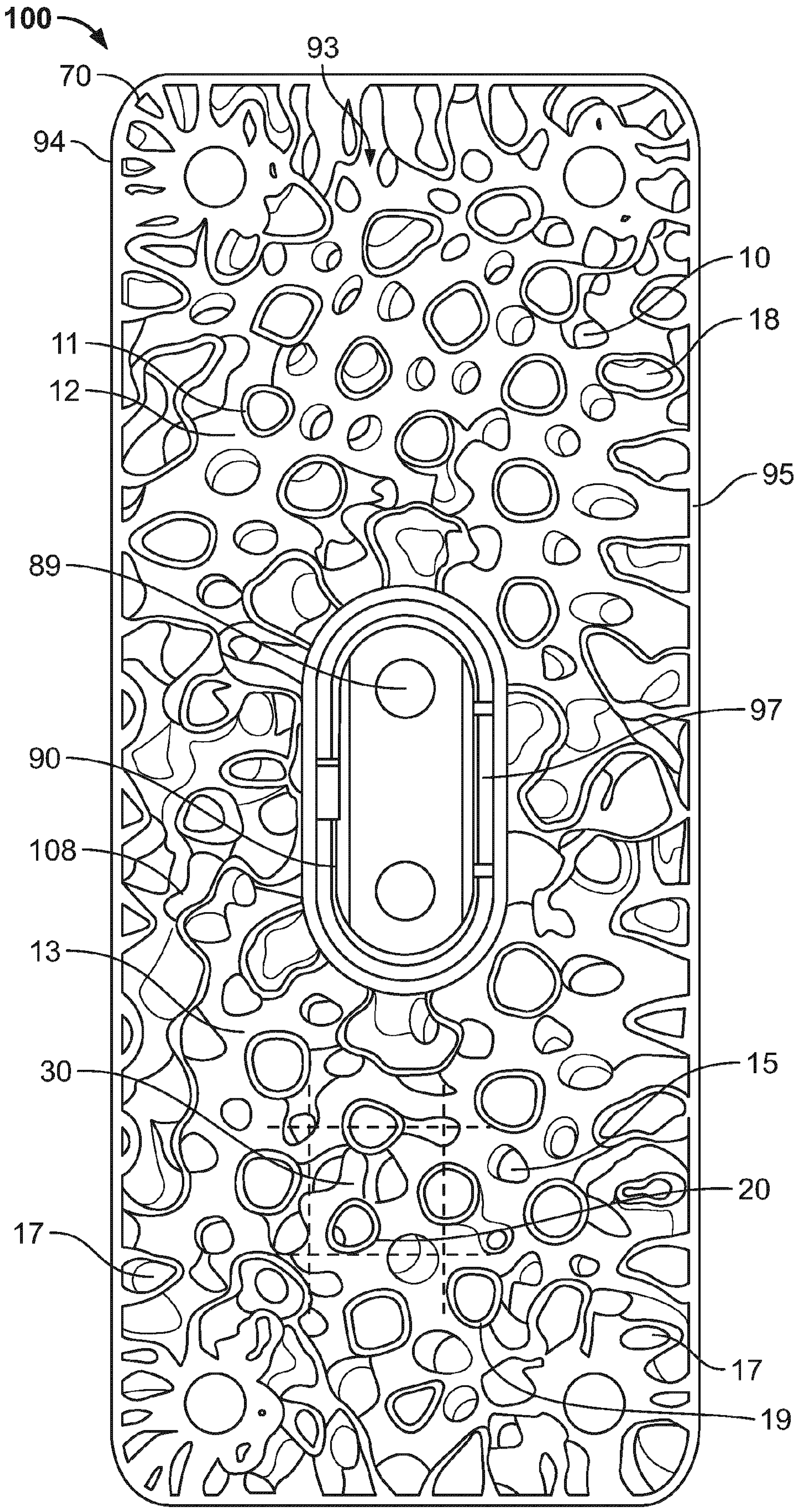
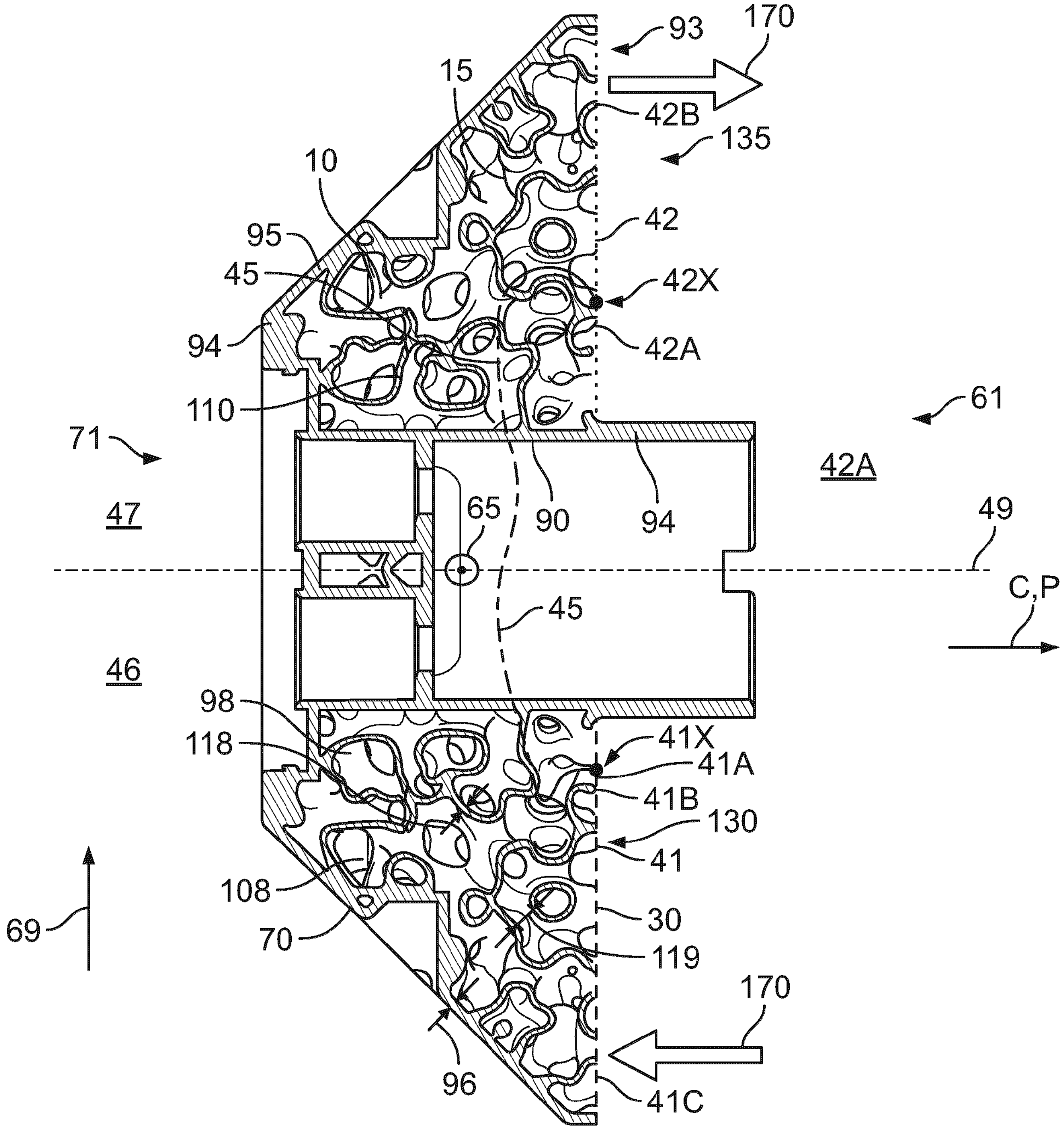


Fig. 3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49
C,P
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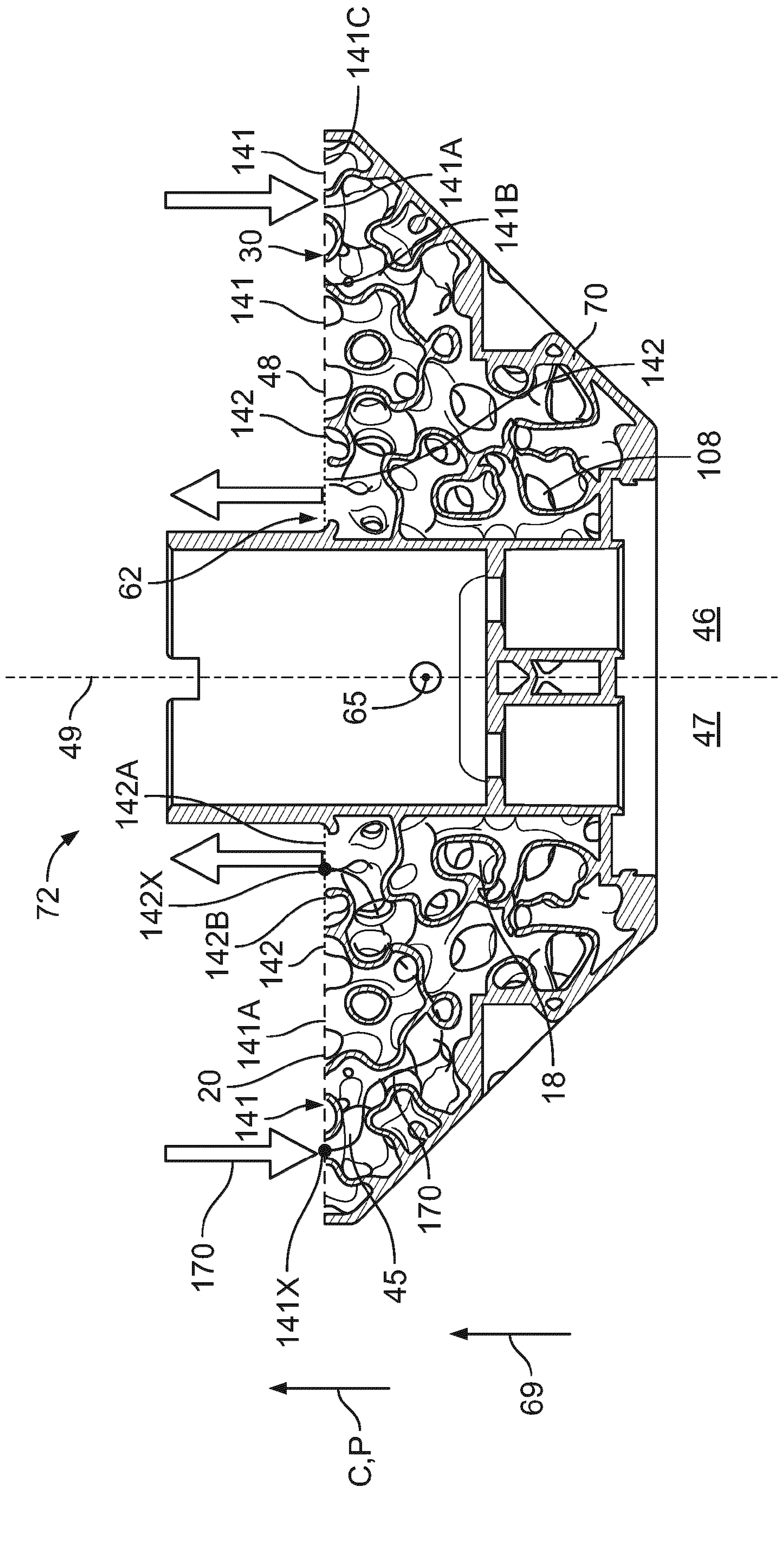
96
41C

Fig. 4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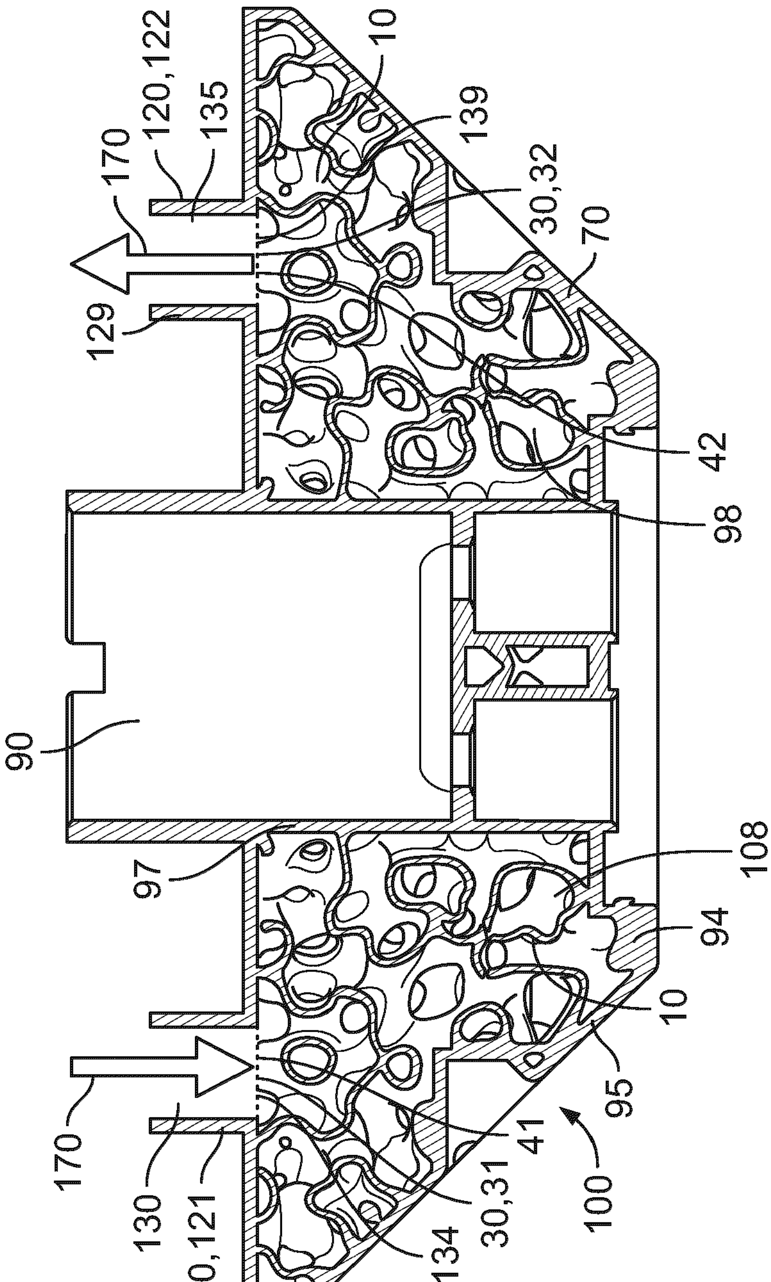
C,P

Fig. 5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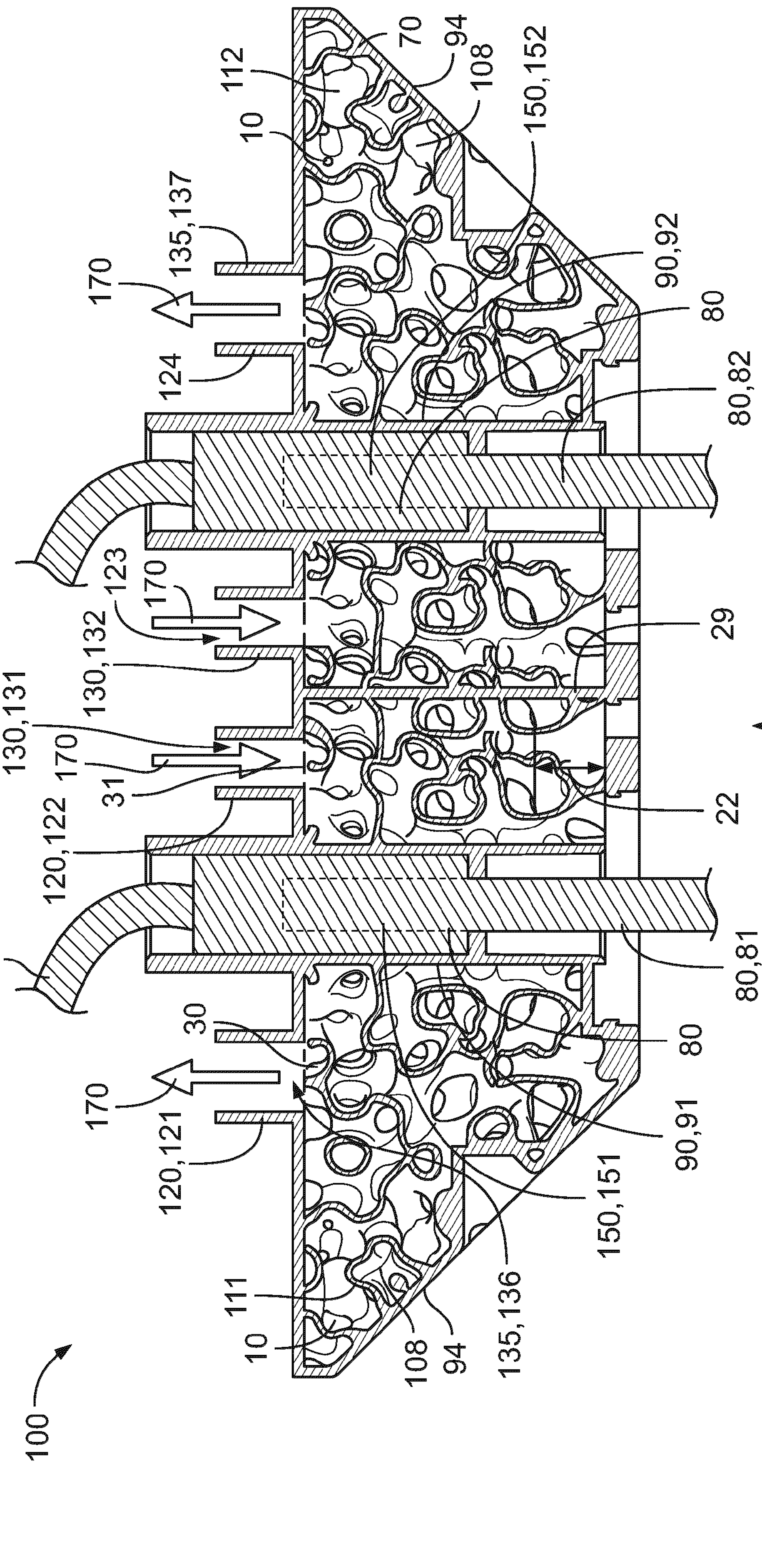
170

Fig. 6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80,82
170
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80
90,92
10
112
108
150,152
94
70
100

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 22 20 1958

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	US 2022/118866 A1 (HAN TAEYOUNG [US] ET AL) 21 April 2022 (2022-04-21) * the whole document * -----	1-15	INV. H01R13/00 H01R13/516 H01R13/533
X	DE 10 2018 108181 A1 (VOLKSWAGEN AG [DE]) 10 October 2019 (2019-10-10) * paragraph [0023]; figures 1-5 * -----	1,13-15	
X	US 2006/068644 A1 (ZAUBER VONN A [US]) 30 March 2006 (2006-03-30) * paragraph [0050]; figures 1-4 * -----	1,13-15	
A	WO 2014/080429 A1 (COUNCIL SCIENT IND RES [IN]) 30 May 2014 (2014-05-30) * abstract; figures 1-4 * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01R

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	31 March 2023	Georgiadis, Ioannis

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 22 20 1958

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31-03-2023

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