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(54) STRUCTURAL ASSEMBLY OF A CELL OF AN ELECTROLYZER, ELECTROLYZER, AND METHOD OF MANUFACTURING SUCH STRUCTURAL ASSEMBLY

(57) The invention relates to a structural assembly of a cell of an electrolyzer of the staple-type having a plurality of cells stacked in an axial direction, the structural assembly comprising a main frame having a mounting surface and a seating surface, a pressure frame arrangement and a membrane arrangement abutting against the seating surface and being sandwiched between main frame and pressure frame arrangement in the axial direction, wherein the common axial extension of the membrane arrangement and the pressure frame arrangement in the assembled state is set by the axial distance between the seating surface and the mounting surface and is reached by an axial pressure force applied in the assembly process, whereby the reduction of the common axial extension is predominantly provided by an axial extension reduction of the pressure frame arrangement.

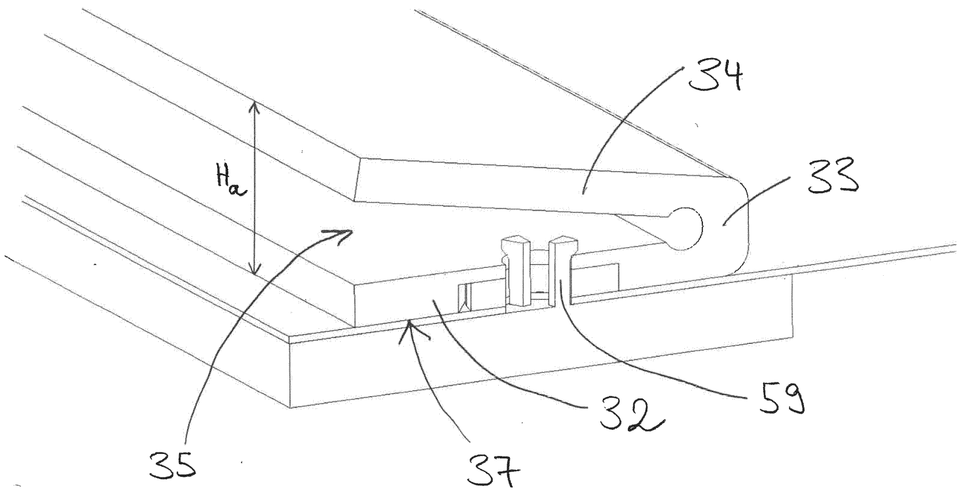

Fig. 3

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Description

[0001] The invention is in the field of electrolyzers of the staple-type having a plurality of cells stacked in an axial direction, and relates in particular to a structural assembly of a cell of such an electrolyzer, the structural assembly comprising a main frame having a mounting surface and a seating surface, a pressure frame arrangement and a membrane arrangement abutting against the seating surface and being sandwiched between main frame and pressure frame arrangement in the axial direction, wherein the common axial extension of the membrane arrangement and the pressure frame arrangement in the assembled state is set by the axial distance between the seating surface and the mounting surface and is reached by an axial pressure force applied in the assembly process.

[0002] Structural assemblies of a cell of an electrolyzer are well known, f.i. from DE 10 2014 010 813 A1. While in this document, an inner reinforcing ring for the main frame is proposed, such reinforcement is not essential for the invention and main frames with or without reinforcement or main frames with outer reinforcement are envisaged regarding the main frame.

[0003] Of course, the membrane (arrangement) needs to be fixed to the main frame. To this end, several methods have been used in the part. These range from screwing the membrane by screws with appropriate washer and sealing arrangement against the main frame. Other ways were to sandwich the membrane between a radially inward protrusion part of the main frame and a counter frame part, which distributes the clamping pressure more uniform over the membrane, the counter frame being fixed to the main frame f.i. by screws.

[0004] In a further technique, the clamping force provided by screws was replaced by an areal pressure force applied during assembly (and acting against elastic counterforce of sealings to appropriately seal the path of the cells between each other and versus the neighboring cells). Thereby, the stiff counter frame acts as pressure frame to compress the membrane in the sandwiching zone during the assembly process. Of course, the axial dimension of the pressure frame is adjusted to allow the assembly process by still keeping, in the assembled state, a sufficient sandwiching pressure force.

[0005] It is an object of the invention to provide such a structural assembly as initially introduced which is improved regarding a combination of satisfying ease of manufacturing on the one hand side and reliability of the operation of an electrolyzer having such structural assembly.

[0006] To this end, the invention provides a structural assembly as initially introduced, which is essentially characterized in that the reduction of the common axial extension is predominantly provided by an axial extension reduction of the pressure frame arrangement.

[0007] Namely, the inventors found out that there is a hidden risk in prior art structural assemblies including pressure frames resulting from tolerances in the machining of the main frame and the pressure frame possibly not fully met or set so close as to be at the risk to be not fully met, or even to be met for the single part but having unfavorable tendencies summing up to not ideal axial dimensions. Such deficiencies may remain undetected in the assembly process or even be undetectable in the assembly process, but may cause an insufficient remaining pressure after assembly, which could then lead to defects in the operation of the electrolyzer.

[0008] Moreover, the inventors found out that such problems can be reduced or avoided by the characterizing feature of the invention, which effectively shifts tolerances for properly assembled cell structures at least in part from (static) axial dimension considerations of the pressure frame to (dynamic) deformation aspects of the pressure frame having the axial extension reduction (effective strain) of the pressure frame arrangement caused by the applied axial pressure force as additional reservoir for tolerance considerations of the single parts of the structural assembly. The "predominantly" refers to the share of axial extension reduction caused by the pressure frame. However, also regarding the circumferential direction in the sense that there may be other additional means for fixing, but preferably still more than 180°, more preferably more than 240°, in particular more than 300° of the full circumference with the axial extension reduction caused by the pressure frame arrangement. The membrane arrangement comprises and in particular may be composed of the membrane of the cell (that is, the arrangement can be just the membrane).

[0009] In a preferred embodiment, said predominant axial extension reduction is predominantly caused by the geometrical shape of the pressure frame arrangement. That is, while generally material properties like the material Young's's modulus could be addressed, the pressure frame assembly is made more resilient by geometry, in particular increasing its elasticity against axial pressure. In this connection it is preferred that the surface area of the cross-section of the pressure frame assembly varies over its axial extension and being in particular lower in an axial intermediate zone. That is, the pressure frame is not configured by a massive body defined by its outer shape, but has cavities, recesses, and/or indentations providing a geometry increasing elasticity against axial pressure forces.

[0010] As a preferred embodiment, a geometry feature of the geometrical shape may comprise a U- or V-formed axial section. However, also other kind of geometrical configurations can be envisaged such as to give the pressure frame properties of springs according to several types of spring mechanism, as clamping springs, torsion springs, or wave springs. That is, elasticity of beam-bending or of moving a lever-like portion against a torque can be implemented into the geometry of the pressure frame arrangement.

[0011] While the pressure frame assembly can be made of a single integral piece, it is preferred that said pressure frame arrangement comprises a plurality of segments in circumferential direction, and is in particular of the topology of a torus and/or closed in circumferential direction. It is to be understood that such topology of a torus gives the form and may comprise a plurality of torus segments corresponding to the segments of the pressure frame arrangement in circumferential direction. This makes manufacture easier in particular for larger electrolyzers having larger effective areas.

[0012] In a further preferred embodiment, the axial stress (axial pressure) onto the membrane/membrane arrangement is provided partly, predominantly or totally by an elastic restoration force to provide in the assembled state sufficient holding force holding the membrane against the main frame. Said axial stress may be larger than 6 N/mm^2, preferably 9 N/mm^2, in particular larger than 12 N/mm^2.

[0013] In a further preferred embodiment, the pressure frame arrangement may have release cavities for reducing elongation in circumferential direction during axial extension reduction. Thereby, further deformation due to forces in circumferential direction may be partly suppressed and their possibly negative effect for seating stability can be suppressed.

[0014] In a further preferred embodiment, the (compressive) strain of the membrane in axial direction is lower than 8%, preferably lower than 6%, in particular lower than 4%, and/or lower than 0,1 mm, preferably lower than 0,07 mm, in particular lower than 0,05 mm.

[0015] This is achievable by adapting the elasticity by geometry of the pressure frame arrangement to the Young's modulus of the membrane such that the axial extension reduction of the combined system is governed by that caused by the geometrical shape of the pressure frame arrangement. Thereby, effectively the full axial extension reduction of the system is provided by the axial extension reduction of the pressure frame arrangement, such that the use of even non-flexible membranes (diaphragms) becomes possible. This increases also the variability in composing the single parts of the structural assembly, in particular allowing for stiff membranes (diaphragms).

[0016] It is to be understood that the abutting of the membrane (diaphragm) against the seating surface can be direct or indirect via an intermediate piece (however, the direct abutting is preferred).

[0017] In this connection it is preferred that an effective Young's modulus of the pressure frame arrangement in axial direction is lower than the Young's modulus of the membrane assembly in axial direction by a factor of at least 1.1, preferably at least 1.2, in particular at least 1.3. The effective Young's modulus of the pressure frame is not that of the material of the pressure frame but that determined by the axial extension reduction including effects by geometrical shape of the pressure frame arrangement at axial pressure forces applied in the assembly process.

[0018] In a further preferred embodiment, the membrane/membrane arrangement has positioning holes matching to positioning pins on the seating surface. This provides for more accurate positioning in the extension plane orthogonal to the staple direction in the assembly process.

[0019] In a further preferred embodiment, elements of the pressure frame assembly may form a chain in circumferential direction, being coupled via a hinged coupling. Axial pins for this coupling may be formed on the chain elements and/or by positioning pins at the seating surface.

[0020] It is to be understood while it is preferred that the pressure force providing for the remaining stress in the assembled state is caused (only) by the external axial pressure force applied in the assembly process (with given relaxed axial dimension of the combined arrangement), stacking one cell upon the other under axial pressure, but is not limited to provision of such exclusive assembly pressure force. For instance, in particular close to the crossover from one pressure frame segment to another one, additional fixing can be provided, f.i. by screws. It is then preferred to decouple such additional fixing from the axial pressure considerations, f.i. by providing that in said portion of the additional fixing, the overall extension in axial direction is lower than the set axial distance between the seating surface and the mounting surface anyway.

[0021] Further, the invention also provides an electrolyzer of the staple-type, having a plurality of cells stacked in an axial direction, one or more thereof, in particular all thereof having a structural assembly according to any of the preceding aspects.

[0022] The invention also provides for a pressure frame arrangement of a structural assembly in accordance with any of the above aspects, in particular having its axial extension reduction predominantly caused by its geometrical shape, that is the above described elasticity by geometry.

[0023] Generally, regarding the axial extension reduction, it is not required that the deformation of the pressure frame arrangement is elastic only with no plastic deformation share. However, the elastic share of the deformation should preferably predominate, and to allow for disassembling the structural assembly and re-assembling the structural assembly to thereby provide for sufficient holding force in the re-assembled state.

[0024] Further, the invention provides a method of manufacturing a pressure frame arrangement in accordance with the above-captioned aspects, comprising the step of providing an outer shape for a pressure frame part, in particular by casting or injection molding, and providing a geometrical shape providing for elasticity by geometry within the forming step and/or an additional material removal step.

[0025] Moreover, the invention provides a method for manufacturing a structural assembly in accordance with any of these aspects, comprising the steps of manufacturing a main frame and manufacturing a pressure frame arrangement in dependency of the axial distance between the mounting surface and the seating surface of the main frame and in particular of the axial extension of the membrane/membrane arrangement such that the reduction of the common axial extension is predominantly provided by the axial extension reduction of the pressure frame arrangement.

[0026] Moreover, the invention provides a method of assembling an electrolyzer of the staple-type, comprising the steps of providing a plurality of electrolyzer cells, assembling the cells between two end plates of the electrolyzer by applying an axial pressure force, thereby reducing the common axial extension of pressure frame arrangement and membrane (arrangement) in axial direction wherein the reduction of the common axial extension is predominantly provided by an axial extension reduction of the pressure frame arrangement.

[0027] The advantages of these methods result from the above and subsequent description, and can in particular be seen in an easier manufacture in view of less strict tolerances, allowing in particular manufacture of single parts of the structural assembly independent from each other and in particular at separate manufacturing locations.

[0028] Further features, details, and advantages of the invention result from the subsequent description with reference to the accompanying figures, wherein

Fig. 1 shows schematically a structural assembly of a cell of an electrolyzer in a perspective view,

Fig. 2 shows an axial section through the structural assembly of Fig. 1 with a pressure frame arrangement shown in the assembled state,

Fig. 3 shows an axial section of the pressure frame arrangement in a relaxed state,

Fig. 4 shows part of the pressure frame arrangement in a perspective view,

Fig. 5 shows another axial section for an optional additional local fixing, and

Fig. 6 shows a chain of pressure frame elements.

[0029] In the perspective view of Fig. 1, one recognizes, drawn in a schematical manner, a main frame 10 having an essentially annular outer shape and an interior 50. At the outer border, a reinforcing part 11 is provided, which could be formed f.i. by several windings of a reinforcing material wound around the main frame 10, to give additional stability against radial pressure forces during operation of the electrolyzer. The inner space 50 is confined by an inner border 53, 54 formed in a stepwise manner (Fig. 2) such as to form a seating surface 57 in the extension plane orthogonal to the staple axis of the electrolyzer. Further, the frame 10 has several axial through-holes 12 and connections therefrom to the interior 50 of manifolds serving to bring electrolyte into the half cells 51, 52 of the inner space 50, divided by membrane 20.

[0030] Membrane 20 is laid upon seating surface 57 and sandwiched by the radially protruding portion of the main frame 10 with the seating surface 57 and a pressure frame arrangement 30. In the subject embodiment, pressure frame arrangement 30 is shown as being formed integrally as a whole part, but may contain a number of pressure frame parts circumferentially abutting one to the next one to thereby form a 360° arrangement of the topology of a torus.

[0031] The membrane 20 is, thus, sandwiched between the seating surface 57 of the main frame 10 and a lower side 37 of the pressure frame. Although not shown, there can be an additional sealing between membrane 20 and surface 57 as part of the membrane arrangement.

[0032] The pressure frame 30, respectively its shown part, is, in this embodiment, not formed massive but has a recess 35 in form of a cut extending, in the shown embodiment, from the radially outer side of pressure frame essentially along the radial and circumferential direction, such as to form an essentially U- or V-shaped axial section as shown in Fig. 2. In one envisaged embodiment, the recess 35 between lower portion 32 and upper portion 34 of pressure frame 30 connected by inner portion 33 extends circumferentially over full 360°. This is, however, only one possible embodiment. In another embodiment, the axial section form according to Fig. 2 may be present for a plurality of circumferential sections which can be separated by other geometry shape, even massive. However, in said case, it is preferred that those connecting segments do not, in particular by lower axial extension, interfere with the deformation under axial pressure force pushing the upper portion 34 versus the lower portion 32 in a sense that the compressive load against membrane 20 is not essentially increased with respect to that applied via the segments with the recess 35.

[0033] In such intermediate segments, there might be (Fig. 5) additional local fixing by means of screws 69 fixing the pressure frame part circumferentially locally against the main frame 10 with defined height of spacing matching for membrane 20 and stress sufficient to fix the membrane 20 preferably without further deformation of the membrane 20. Such local additional fixing could be provided in particular close to the crossover from one pressure frame part to the next one and so on, or additionally at some intermediate locations of one pressure frame part 30.

[0034] It is to be understood that a selected number of pressure frame parts is not particularly restricted, there can be three or a higher number, apart from the general possibility to create an integral pressure frame. In the case of additional fixing by screws, protrusions 59 can be used to have an inner thread to receive the screws. Alternatively or additionally, such protruding pins 59 (also without inner threads) can also be used as positioning pins for positioning corresponding holes of membrane 20 within the assembly process, the lower portion 32 of pressure frame 30 having corresponding axial openings (Fig. 3).

[0035] Further, sealing means can appropriately be provided as generally known by the skilled artisan as (double) annular sealing ring 13 around manifold 12, an outer sealing ring 14 (Fig. 1) or, if desired, sealings between membrane 20 and the side of the pressure frame 30 facing the main frame 10.

[0036] As can be best seen by comparison of Fig. 3 and Fig. 2, in a relaxed state, the height extension H_a which is the maximum height extension in the relaxed state, is higher than in the assembly state shown in Fig. 2. This is due to an axial pressure force during assembly, which positions an electrode, f.i. in form of a bipolar plate 60 against mounting surface 14 of the main frame to set a height Ho as axial distance between seating surface 57 and mounting surface 14 which correspond, in the assembled state, to the axial height H_p+H_m, H_p denoting the axial extension of the pressure frame and H_m that of the membrane.

[0037] It is to be understood that, in the assembled state, not withstanding reduction of said common axial extension due to the axial pressure force, there is still sufficient remaining stress to urge pressure frame part 30 against the main frame with the membrane 20 sandwiched inbetween, however, the resistivity of the membrane against axial compression can be selected larger than the resistivity of pressure part against axial extension reduction, due to the geometrical shape provided in this embodiment by recess 35. In this way, pressure frame 30 acts like a resilient, at least partly elastic spring against axial compression, the elastic part thereof being sufficient to provide for the required holding force for membrane 20 without significantly deforming the membrane 20.

[0038] Thereby, on the one hand side, membrane 20 can be selected from a broader range of membrane types and structures. Regarding its structure, there is no more need to provide for the capability of the membrane to be compressed without risk of losing its functionality, more stiff membranes can be used. On the other hand side, manufacture of the combination of main frame 10 and pressure frame arrangement 30 can be performed with less strict tolerances otherwise needed to meet the required interplay between compressibility against Young's modulus of the pressure frame in axial direction for a strain to be in tolerance with the step between mounting surface 14 and seating surface 57 while still keeping sufficient stress to sandwich the membrane 20.

[0039] As is shown in Fig. 4, additional cavities or openings 36, in particular in form of slits, can be provided, also reaching close to the inner portion 33 of pressure frame 30 to act as release cavities against circumferential pressure forces reducing circumferential elongation caused by axial compression, respectively by a bending of the crossover portion between inner portion 33 and lower end upper portion 32, 34. However, depending on material and pressure matching, those additional openings 36 may also be omitted. In the embodiment of Fig. 6, on recognizes that part of the pressure frame arrangement may also be in form of a chain with chain elements 30x. The coupling thereof can be a hinged coupling, f.i. by pins, in particular by pins 59 at the seating surface 57. The membrane may be formed from materials as known in the art.

[0040] The pressure frame parts 30 may be formed from a castable and/or injection moldable material, in particular a resin.

[0041] The Young's modulus of the material of the pressure frame part as such can be in particular larger than the Young's modulus of the membrane. Notwithstanding, due to the geometrical shape of pressure frame part of preferred embodiments providing it with elastic behavior in axial direction, it is mainly and in particular effectively totally the geometrical structure determining the axial extension reduction of the pressure frame 30 and the combination of pressure frame 30 and membrane 20. Thereby, although some axial compression of the membrane might be taken into account, the machining condition for maintaining tolerances can be improved due to larger strains of the system for usual axial pressure forces while still keeping enough stress for the proper sandwiching clamping force of the system in the assembled state.

[0042] In a preferred way of manufacturing the pressure frame parts for the pressure frame arrangement, the outer shape of pressure frame 30 or its parts could be formed within a forming step, as f.i. die-casting or injection molding, while recess 35 and possibly other cavities as 36 are formed departing from the form obtained by the molding step via material removal as any cutting process as mechanical cutting or laser cutting. However, it is also envisaged to provide for the geometrical shape of the pressure frame part at least partly or even totally within the molding step, which is even preferred so as to reduce the number of manufacturing steps.

[0043] Further, regarding the manufacturing process, it is also envisaged to form the main frame at a first location according to manufacturing parameters including among other the axial distance between seating surface 57 and mounting surface 14 including its tolerance, and to manufacture, at a second location different from the first location, pressure frame parts of the pressure frame arrangement in accordance with manufacturing parameters including said axial distance and the height extension and a tolerance thereof of membrane 20, preferably also a minimum Young's modulus thereof. However, the second location of manufacturing of the pressure frame parts could also be the same as that of the main frame.

[0044] In a further preferred embodiment, the forming step of the outer shape of pressure frame 30 and optionally of part of the geometrical shape providing axial elasticity by geometry of pressure frame 30 are formed according to first manufacturing data independent of actual data for the membrane, and only a material removal step is executed in dependency of parameters of the membrane. Thereby, the first molding step can be executed in a uniform way independent of the final choice of the membrane, while the more flexible manufacturing step of material removal considers the membrane, thereby allowing enhanced variability in the choice of the membrane, even a later re-consideration in case of f.i. problems in providing the originally intended membrane.

[0045] Also here, the shifting of realization of constraints from sensitive manufacturing tolerances regarding the dimension of the parts to the force side involving larger amounts of axial extension reductions makes manufacturing easier and increases variability in the composition of the structural assembly.

[0046] It is to be understood that the details of the described embodiments are not to be considered restrictive to the subject invention. Rather, the features of the above description and of the subsequent claims, alone or in combination, can be essential for the invention in its various embodiments.

Claims

1. Structural assembly (100) of a cell of an electrolyzer of the staple-type having a plurality of cells stacked in an axial direction, the structural assembly comprising
a main frame (10) having a mounting surface (14) and a seating surface (57), a pressure frame arrangement (30) and a membrane arrangement (20) abutting against the seating surface and being sandwiched between main frame and pressure frame arrangement in the axial direction, wherein the common axial extension (H_p+H_m) of the membrane arrangement and the pressure frame arrangement in the assembled state is set by the axial distance (H_o) between the seating surface and the mounting surface and is reached by an axial pressure force applied in the assembly process,
characterized in that the reduction of the common axial extension is predominantly provided by an axial extension reduction of the pressure frame arrangement.

2. Structural assembly according to claim 1, said predominant axial extension reduction being predominantly caused by the geometrical shape (32, 33, 34, 35) of the pressure frame arrangement.

3. Structural assembly according to claim 1 or 2, the surface area of the cross-section of the pressure frame assembly varying over its axial extension and being in particular lower in an axial intermediate zone.

4. Structural assembly according to any of the preceding claims, a geometry feature of the geometrical shape comprising a U- or V-formed axial section (32, 33, 34).

5. Structural assembly according to any of the preceding claims, said pressure frame arrangement comprising a plurality of segments in circumferential direction, and is in particular of the topology of a torus and/or closed in circumferential direction.

6. Structural assembly according to any of the preceding claims, wherein the axial stress onto the membrane arrangement in the assembled state is at least locally provided, at least partly, in particular predominantly or totally by an elastic restoration force of the pressure frame arrangement.

7. Structural assembly according to any of the preceding claims, wherein the pressure frame arrangement has release cavities (36) for reducing elongation in circumferential direction during axial extension reduction.

8. Structural assembly according to any of the preceding claims, wherein the strain of the membrane arrangement in axial direction is lower than 80%, preferably lower than 60%, in particular lower than 40% of that of the pressure frame assembly, at least locally.

9. Structural assembly according to any of the preceding claims, the membrane arrangement (20) having positioning holes matching to positioning pins (59) on the seating surface (57).

10. Electrolyzer of the staple-type, having a plurality of cells stacked in an axial direction, one or more thereof, in particular all thereof having a structural assembly according to any of the preceding claims.

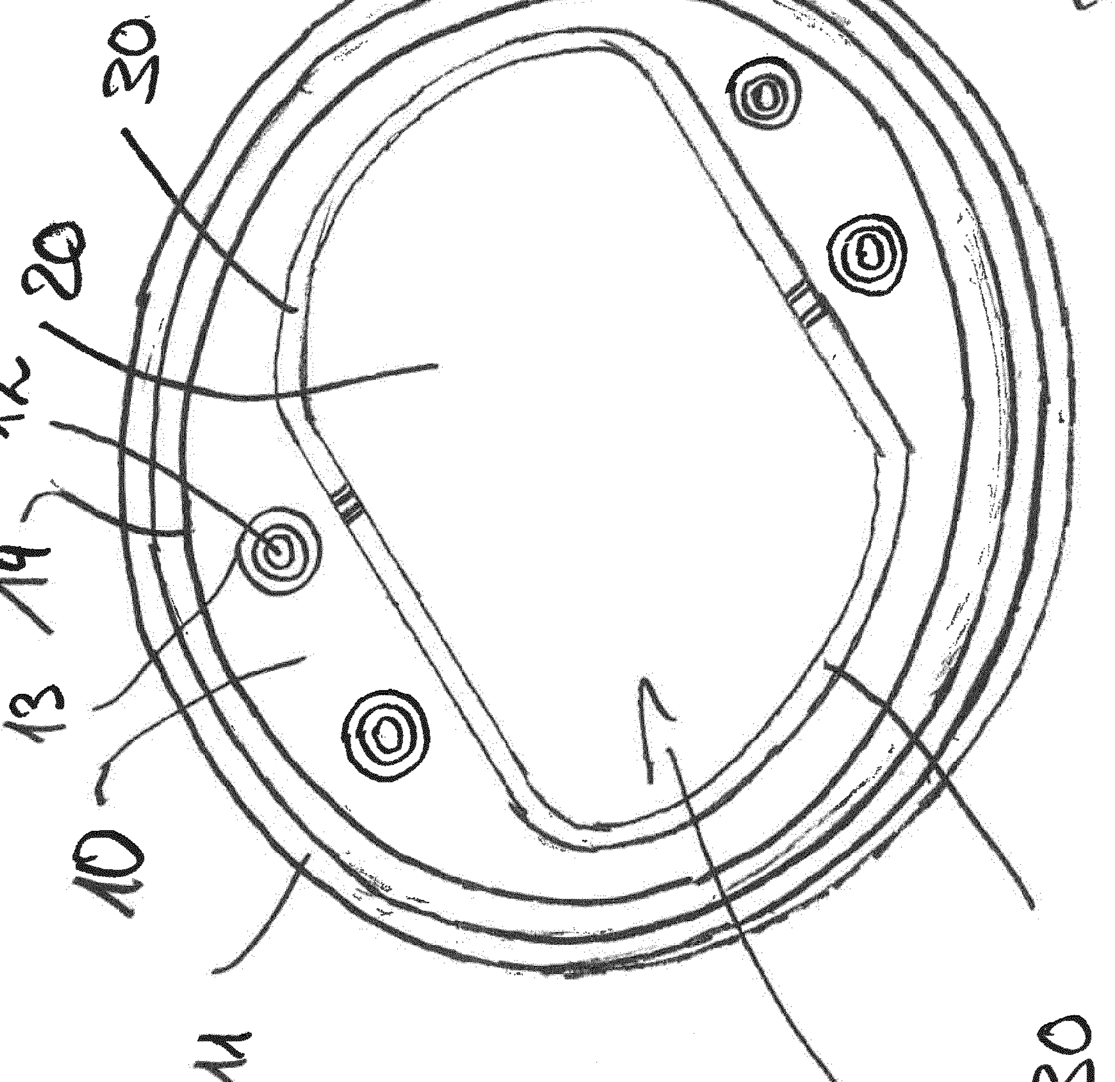
11. Pressure frame arrangement of a structural assembly in accordance with any of the claims 1 to 10.

12. Method of manufacturing a pressure frame arrangement of claim 11, comprising the step of providing an outer shape for a pressure frame part, in particular by casting or injection molding, and providing a geometrical shape providing for elasticity by geometry within the forming step and/or an additional material removal step.

13. Method of manufacturing a structural assembly in accordance with any of claims 1 to 9, comprising the steps of manufacturing a main frame and manufacturing a pressure frame arrangement in dependency of the axial distance between the mounting surface and the seating surface of the main frame and in particular of the axial extension of the membrane arrangement such that the reduction of the common axial extension is predominantly provided by the axial extension reduction of the pressure frame arrangement.

14. Method of assembling an electrolyzer of the staple-type, comprising the steps of providing a plurality of electrolyzer cells, assembling the cells between two end plates of the electrolyzer by applying an axial pressure force, thereby reducing the common axial extension of a pressure frame arrangement and a membrane in axial direction wherein the reduction of the common axial extension is predominantly provided by an axial extension reduction of the pressure frame arrangement.

Fig. 1



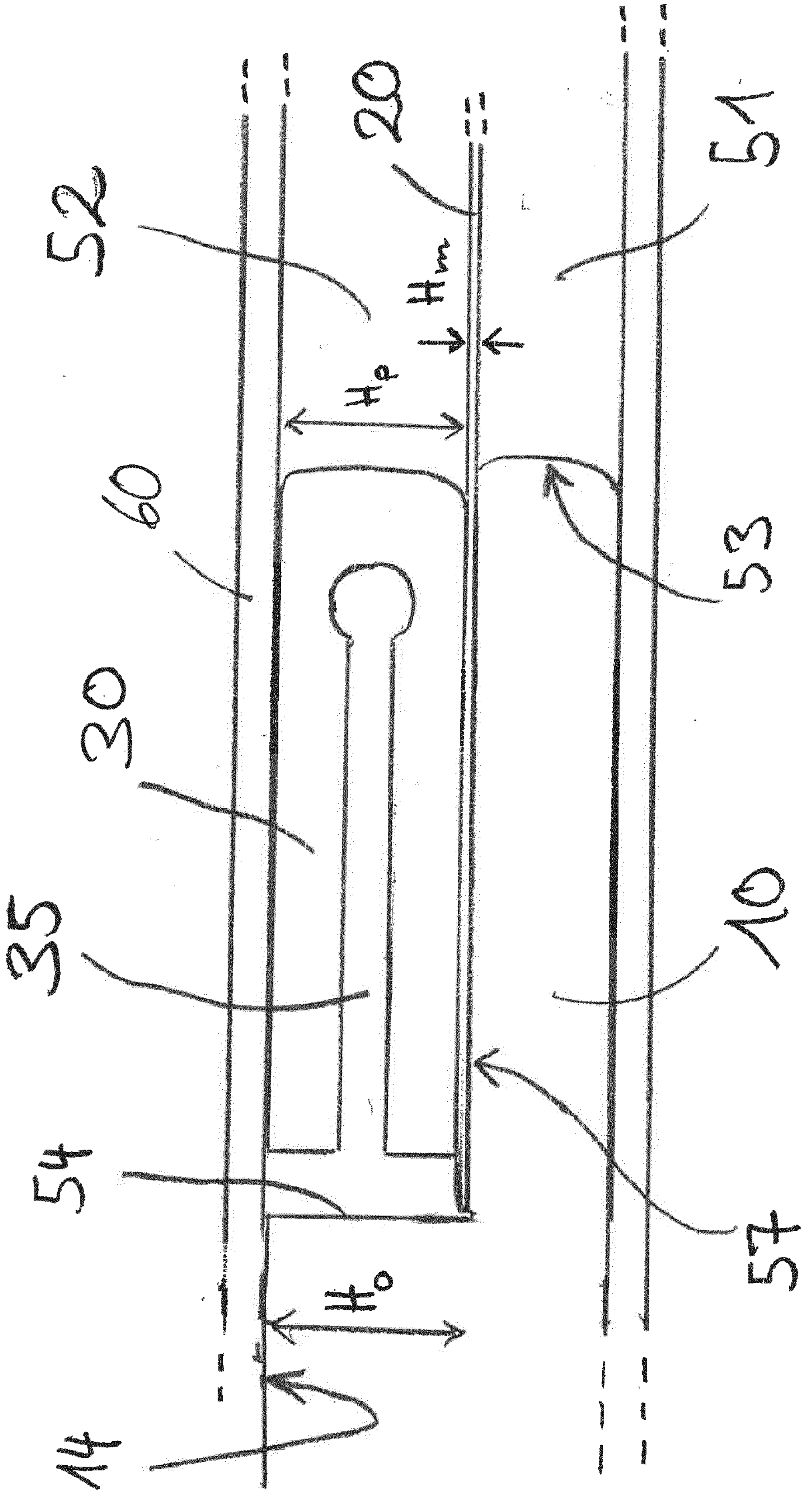


Fig. 2

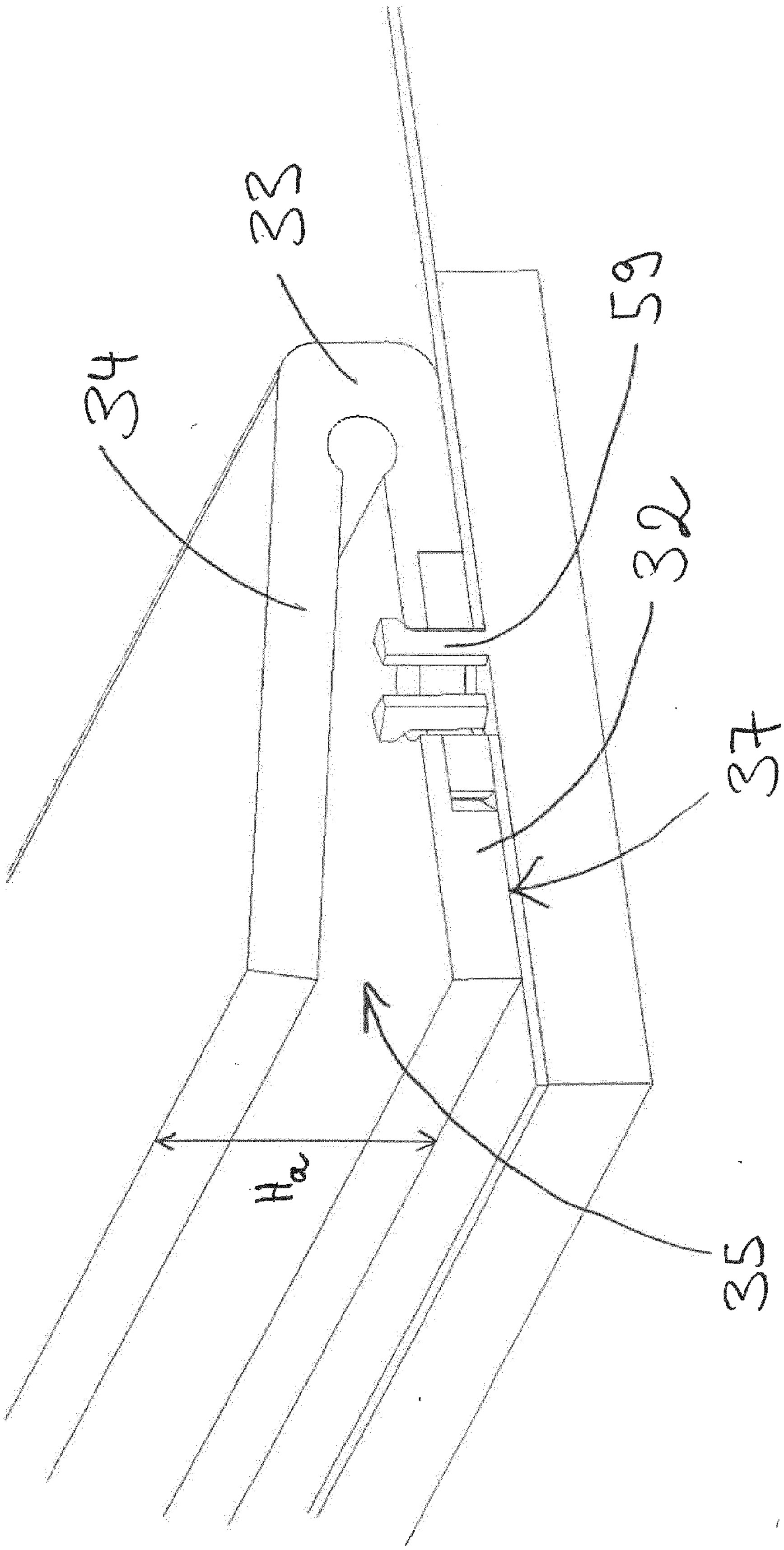


Fig. 3

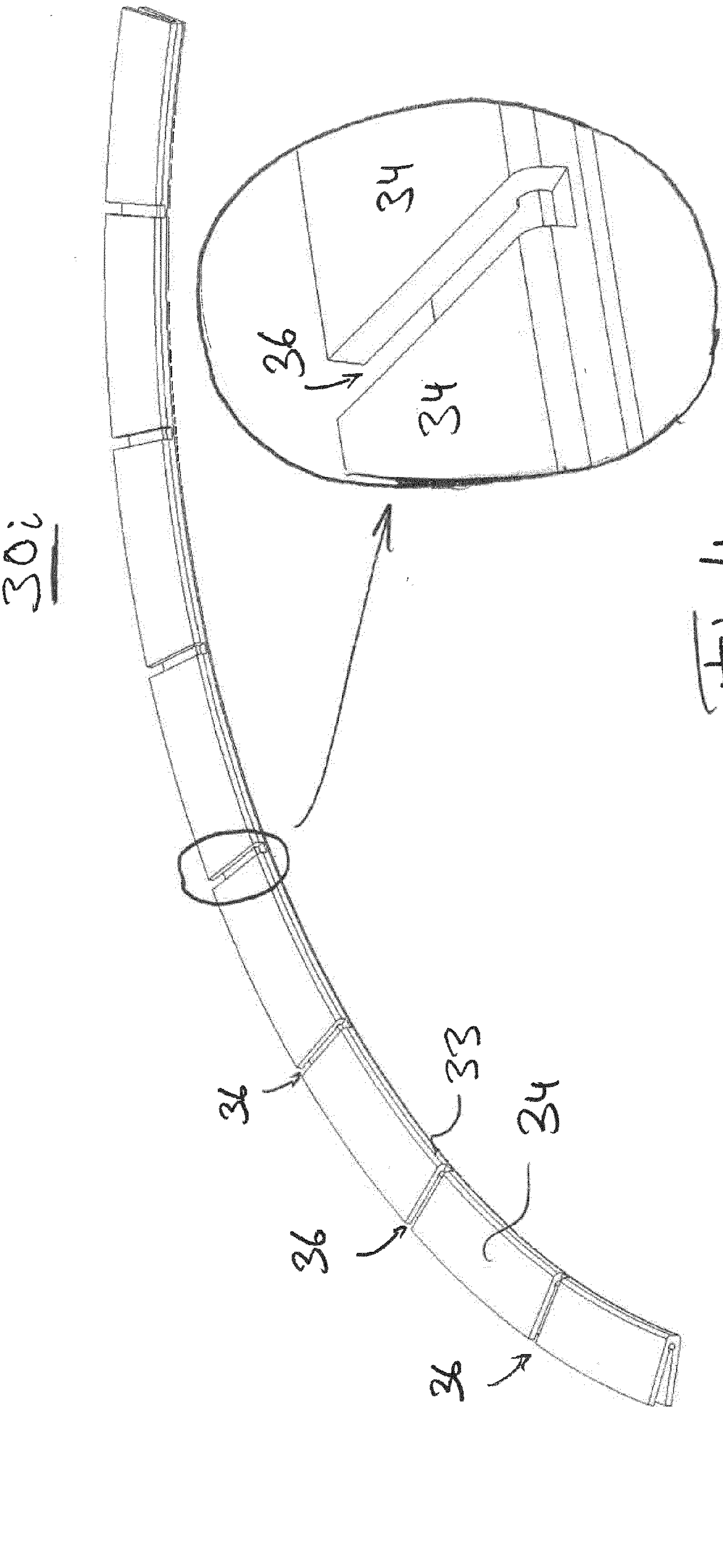


Fig. 4

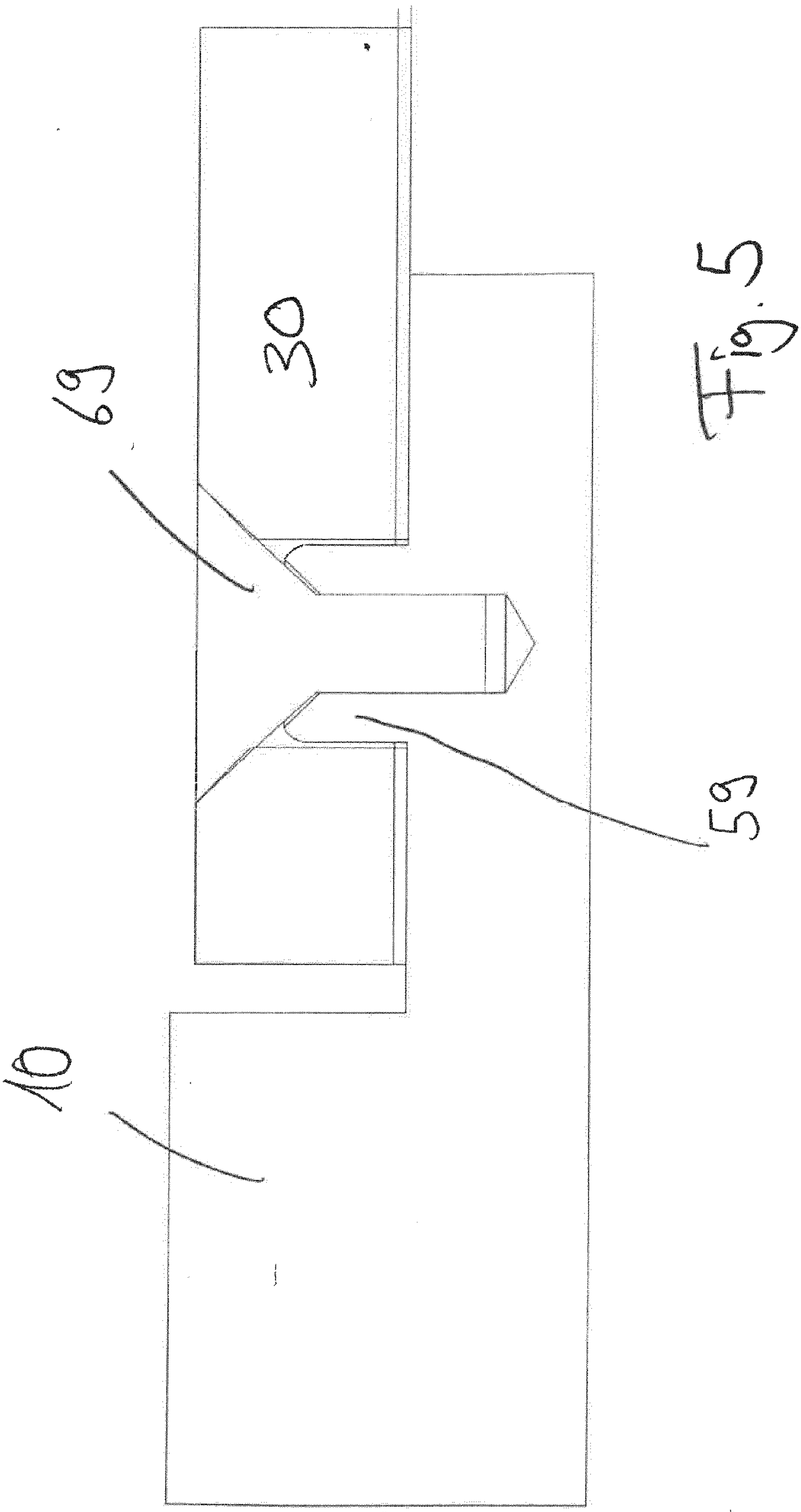


Fig. 5

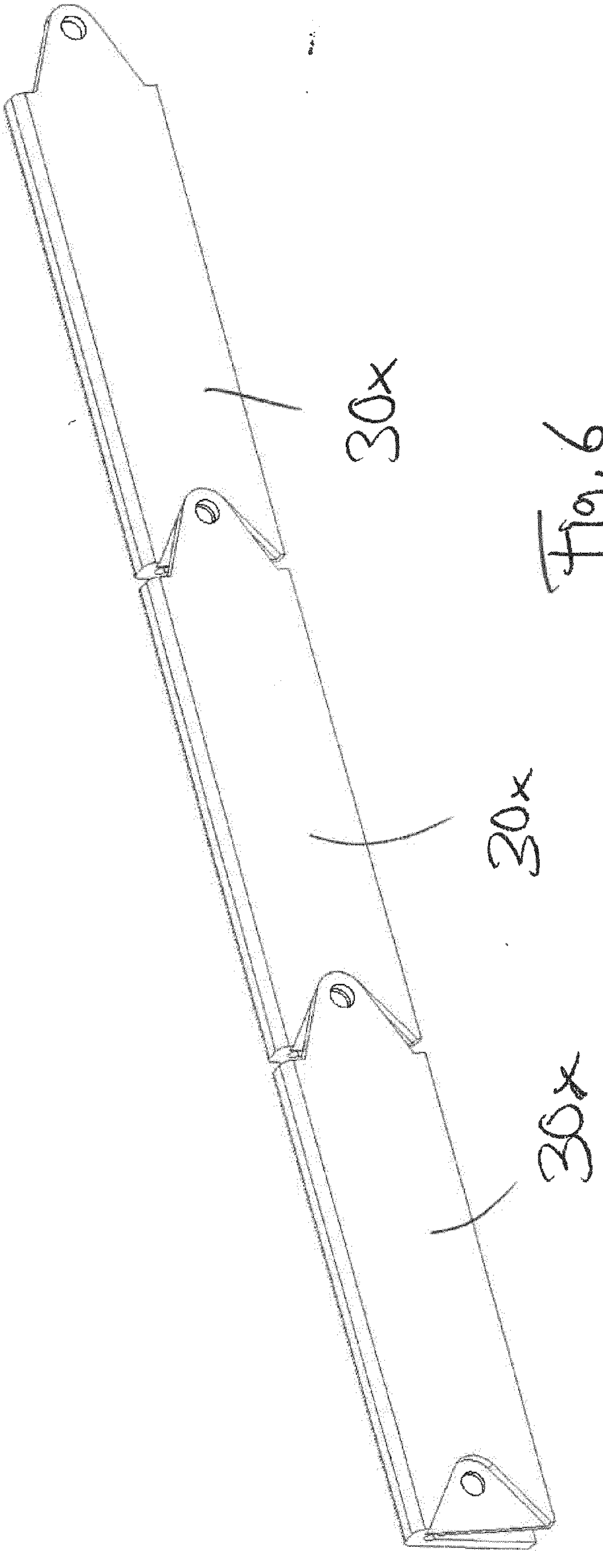


Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 21 16 6519

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

C25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	15 September 2021	Leu, Oana

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

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

EP 21 16 6519

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