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(54) COMPOSITE PISTON ACCUMULATOR

VERBUNDKOLBENSPEICHER

ACCUMULATEUR COMPOSITE À PISTON

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Description

Field of the invention

[0001] The present invention relates to hydropneumatic accumulators. More specifically, the invention relates to accumulators for storage and delivery of hydraulic energy, i.e. storage and delivery of pressurized fluids. The accumulators of the invention are useful for a number of industries and purposes.

Background of the invention and prior art

[0002] Currently accumulators, particularly piston accumulators, are made of metal, since metal is a very reliable construction material having well known properties, such as limited elongation due to a high modulus of elasticity. However, hoop stress in a pressure container may even for moderate pressures require a large wall thickness in order to maintain the integrity and avoid leakage over the piston. As a result, the weight of metal accumulators becomes high, limiting the utilization in several fields and industries, like aircraft, defense, wind energy, oil and gas and sporting goods.

[0003] Even though a demand for lighter accumulators has existed for many years, accumulators have in practice not been manufactured in composite materials since several problems have occurred. Leakage over the piston has been the main problem, but also leakage from end caps has been a severe problem.

[0004] In patent publication US 2005/0194054 A1 a lightweight low permeation piston-in-sleeve accumulator is described and illustrated, comprising a lightweight composite cylindrical outer pressure vessel with rounded ends, with or without a liner inside the composite cylindrical outer pressure vessel, a closeable port positioned within one end of the vessel body, a cylindrical nonpermeable sleeve, and a piston slidably disposed within said sleeve. No end caps are described or illustrated. The piston has concavity on only one side.

[0005] In patent publication EP 2 239 468 A1 a piston accumulator with a cylindrical body made of polymer, a piston and end caps. The end caps are slightly concave. The piston has concavity on only one side.

[0006] The objective of the present invention is to provide composite accumulators reducing or eliminating the above-mention problems.

Summary of the invention

[0007] The invention provides an accumulator for storage and delivery of hydraulic energy, comprising a cylindrical accumulator chamber inside a wall part and one or two end sections, a piston arranged in the accumulator chamber and at least one seal arranged between the piston and wall part, the piston with seal has dimension to fit into the accumulator chamber dividing the accumulator chamber into two parts, the wall part is made of composite material. The accumulator is distinctive in that the piston has concave end surfaces facing each respective accumulator chamber part, the shape of the concavity and the material properties of the piston are adapted such that the piston expands similarly as the wall section as the pressure varies, such that the piston with seal separate the accumulator chamber parts sealingly even though the pressure varies broadly, wherein the radial thickness of the piston Tp near the opening of said concavity and the wall thickness Tw, and the modulus of elasticity of the piston Ep and wall Ew, respectively, are such that

$$Tp/Tw \leq Ew/Ep \quad .$$

[0008] The operation pressure of the accumulator can be in a range of at least 1-690 bar, more preferably 1-1000 bar, and most preferably 1-2500 bar or even broader for the best embodiments, without leakage. No previously known composite piston accumulators can operate without leakage at comparable pressure ranges.

[0009] The term that the wall part is made of composite material means that the wall part do not comprise neither a metal matrix nor a metal liner. The wall is preferably made of a polymer matrix with reinforcing fibres such as epoxy with carbon fibres, but the wall may include a gas tight non-metal liner. The composite material matrix can be an epoxy or for example a thermoplastic polymer. The reinforcing fibres are most preferable carbon fibres, but also glass fibres or other fibres can be used, even metal fibres or metal strands. A gas tight seal is preferably arranged on the inner side of the wall, the gas tight seal can be a gas tight polymer such as PE (polyethylene) or a gas tight non-metal composite, such as a Teflon (PTFE) sprayed composite, which are commercially available. Accordingly, the accumulator has a non metal matrix composite wall part, with or without a gas tight non metal liner.

The piston is made of composite material, polymer or metal, preferably it is made of composite material or a polymer such as PEEK (polyether ether ketone) PEEK GF (polyetheretherketone glass fibre reinforced) or PEEK CF (polyetheretherketone carbon fibre reinforced).. Composite material pistons may preferably comprise a magnet or other means facilitating detection of piston position using sensors, such as Hall effect sensors, from outside the wall.

[0010] The concavity of the end faces of the piston preferably is in the form of a circle or ellipse section in cross section, or ball or ellipsoid section or similar in three dimensions, the tangent angle or angle of intersection of which exceed 30°, preferably 45°, most preferably 60° from a hypothetical flat bottom of said concave end face. Said angle is preferably 90°, i.e. parallel with the cylinder axis near and at the periphery of the concavity, which is best with respect to said expansion, and facilitates man-

ufacture.

[0011] According to the invention, the radial thickness of the piston Tp near the opening of said concavity and the wall part thickness Tw, and the modulus of elasticity of the piston material Ep and wall material Ew, respectively, are such that ($Tp/Tw \leq Ew/Ep$). Another possibility, not being part of the invention, is that ($Dw/Dp \times Tp/Tw \leq Ew/Ep$), where Dw and Dp are the diameters where radial pressure components act on the wall and piston, respectively. The accumulator comprises end sections such as one or two end caps, preferably two, made of composite material, polymer or metallic material, preferably composite material. At least one of the end caps has a feedthrough or opening. Preferably the accumulator comprises two threaded end caps, the wall part comprises corresponding threads, either in a composite, polymer or metallic material insert or in the inner wall surface at the ends. The insert, if used, preferably has larger outer grooves, threads, pins or canals distributing the shear force over a larger area than the internal threads. Accordingly, the wall section, inside either end, preferably comprises rough grooves or threads over a first distance, to which a metal or composite insert or sleeve is arranged, the insert or sleeve has adapted external rough grooves, pins or threads on the outside over said first distance and finer threads is arranged, matching end cap threads, on the inside over a second distance shorter than the first distance. The wall is bonded or wound firmly to the insert or sleeve, if present, for avoiding leakage paths and improving strength, but it can be non-bonded, such as threaded and optionally including seals. The windings or fibres, such as carbon fibre windings, are preferably arranged in several angles to provide hoop strength, axial strength and locking of the wall section to the insert. Axial reinforcing fibres are preferably locked to the external rough grooves or threads or pins of the insert by outside hoop fibres.

[0012] For embodiments with insert and a gas tight liner, a seal is preferably arranged to seal between the gas tight liner and the end cap, thereby reducing the number of leakage paths. The gas tight liner preferably extends onto the inner surface of the insert and the end cap preferably has a concave inner side extending over the seal and liner. Such embodiment will in general be the most preferred embodiment, since high pressure and large range of pressure can be handled better, since the seal will be locked harder between the end cap and liner with increasing pressure.

[0013] Preferably the accumulator comprises end caps having a concave surface toward the accumulator chamber, the shape of the concavity and the material properties of the end caps are adapted such that the end cap expands similarly as the wall section as the pressure varies and preferably seals are arranged outside the periphery of the concavity, sealing between the end cap and either the wall part, a gas tight liner or an insert. Similar as for the end faces of the piston, the concavity preferably is in cross section in the form of a circle or ellipse section, the tangent angle or angle of intersection of which exceed 30°, preferably 45°, most preferably 60° from a hypothetical flat bottom of said end cap face. Said angle is preferably 90°, which is best with respect to said expansion, and facilitates manufacture.

[0014] The concave piston end faces, and optionally the concave inner end cap faces, provide a hoop stress component resulting in radial expansion or contraction of piston and end caps with varying pressure, respectively, similarly as for the wall of the cylindrical accumulator chamber. Elliptical faces also means superelliptoidic faces, which can be preferable for using less material. The concavity can also be a cylindrical bore in the end faces, preferably with rounded inner corner or edge, leaving a sufficiently thick sleeve-like section on either side of the piston or inner side of the end cap, which represents a preferred embodiment. The material properties and dimensions are chosen so as to balance the deformations in order to avoid gaps for leakage.

[0015] The surface roughness, on the inner surface of the cylindrical accumulator chamber and the sealing surfaces on the piston and end caps, are preferably 0,4 μm or finer, as measured according to DIN EN ISO 4287.

Figures

[0016] The invention is illustrated with three figures, namely:

Figure 1 is a sketch and in part longitudinal section of an accumulator according to the present invention,
Figure 2 is a cross section of a piston of an accumulator of the present invention, and
Figure 3 is a sketch and in part longitudinal section of another accumulator according to the present invention.

Detailed description

[0017] Reference is first made to Figure 1, illustrating an accumulator 8 of the invention. Half of the accumulator, i.e. one side of the centre line, is illustrated in section. More specifically, the accumulator 8 comprises a cylindrical accumulator chamber inside a composite wall part 3 and one or two end sections 1, a piston 4 arranged in the accumulator chamber and at least one seal 6,7 arranged between the piston 4 and wall part 3, the piston 4 with seal 6,7 has dimension to fit into the accumulator chamber dividing the accumulator chamber into two parts C1 and C2, respectively. The piston 4 has concave end surfaces 4a, 4b facing each respective accumulator chamber part. Item 5 is a guide ring, seal 6 is a primary seal whilst seal 7 is a secondary seal. Item 2 is an insert or sleeve or end ring with two relatively large grooves toward the wall section in order to distribute the shear stress to a larger area. In addition to the wall part 3, also the piston 4 is made of composite. In the illustrated embodiment, end caps 1 and insert 2 are made of stainless

steel, however in other preferable embodiments one or both of said items can be made of composite material or polymer, which reduce the weight further. End caps and inserts can alternatively be made in titanium or aluminium. The wall part 3 as illustrated is made of composite material with epoxy matrix and reinforcing carbon fibres wound in order to increase hoop stress strength.

[0018] Reference is made to Figure 2, illustrating an embodiment of a carbon fibre composite piston 4, according to the invention, for use in an accumulator of the invention. A similar design can preferably also be used for end caps. Pistons and end caps having concave surfaces facing the accumulator chamber, and shape of the concavity and material properties adapted such that the piston or end cap expands similarly as the wall section as the pressure varies in a range of 1 - 690 bar or wider, are embodiments of the invention. The piston illustrated in Fig. 2 includes a magnet 9 for easier detection of piston position from outside the wall part. The magnet could alternatively be arranged around the periphery if the piston.

[0019] Figure 3 is a sketch and in part longitudinal section of another accumulator 8 according to the present invention. For this accumulator the piston 4 is similar as for the embodiment illustrated in Fig.1, but the end caps 1 have concave inner faces, a gas tight liner 10 is arranged inside a cylindrical composite wall part 3 and the liner 10 extends into the space between an insert 2 and the end cap on either side. In each of said spaces, a seal 11 is arranged. Pressure in the accumulator chambers C1 and C2 will due to the concavity provide a radial pressure component on the end caps 1 and piston 4, which radial pressure component increases with pressure and improves the sealing properties at increasing pressure. If the composite wall section is sufficiently gas tight, the gas tight liner can be omitted and the seals can be arranged between the end cap and either the composite wall or an insert.

[0020] The composite material, how it is arranged and how the parts of the accumulator are manufactured can be varied broadly, using good engineering practice. Further information can be found in reference textbooks such as: Graphite/Epoxy: Daniel, I.M., and Ori, I., Engineering Mechanics of Composite Materials, Oxford University Press, 1994, and Carbon/Epoxy: Barbero, E.J., Introduction to Composite Materials Design, Taylor and Francis, 1999.

Examples

[0021] For a wall part of carbon fiber epoxy composite, having a specific internal volume, the weight is 0,15 that of a corresponding carbon steel wall part and also 0,15 that of a corresponding stainless steel wall part. By manufacturing also the piston and end caps in carbon fiber composite material, the accumulator weight can be reduced to about 0,15 that of a corresponding steel accumulator. The accumulator of the invention is also very favourable over aluminium accumulators, as the specific strength (S_u/φ, that is ultimate tensile strength / density) of carbon fibre composites is about ten times higher and the specific stiffness (E/φ, that is modulus of elasticity / density) is about three times higher than for aluminium, respectively. Corresponding values for specific strength and specific stiffness for graphite composites compared to aluminium are about 3,2 and 7, respectively.

[0022] A piston accumulator according to the present invention for a specific pressure and volume, with metal end caps, weights 32 kg. A corresponding accumulator of acid resistant stainless steel weights 129 kg. Accordingly, the accumulator of the invention can be transported and installed easily, without cranes.

[0023] The accumulators of the invention may comprise any features as illustrated or described in any operative combination, which combinations are embodiments of the invention.

Claims

1. Accumulator (8) for storage and delivery of hydraulic energy, comprising a cylindrical accumulator chamber inside a wall part (3) and one or two end sections (1), a piston (4) arranged in the accumulator chamber and at least one seal (6,7) arranged between the piston (4) and wall part (3), the piston (4) with seal (6,7) has dimension to fit into the accumulator chamber dividing the accumulator chamber into two parts (C1,C2), the wall part (3) is made of composite material, **characterised in that** the piston (4) has concave end surfaces (4a, 4b) facing each respective accumulator chamber part (C1, C2), the shape of the concavity and the material properties of the piston (4) are adapted such that the piston (4) expands similarly as the wall section (3) as the pressure varies, such that the piston (4) with seal (6,7) separate the accumulator chambers parts (C1, C2) sealingly even though the pressure varies broadly, wherein the radial thickness of the piston Tp near the opening of said concavity and the wall part thickness Tw, and the modulus of elasticity of the piston material Ep and wall material Ew, respectively, are such that ($Tp/Tw \leq Ew/Ep$).

2. Accumulator according to claim 1, **characterised in that** the piston is made of composite or polymer material.

3. Accumulator according to claim 1, **characterised in that** the concavity of the end faces of the piston is in the form of a circle or ellipse section, or ball or ellipsoid section, the tangent angle or angle of intersection of which exceed 30°, from a hypothetical flat bottom of said concave end face.

4. Accumulator according to claim 1, **characterised in**

that the accumulator comprises two end sections in the form of end caps made of composite material or metallic material such as stainless steel, preferably each end cap has a through opening for fluid, preferably each end cap is threaded and the wall part comprises corresponding threads, either in a insert or in the inner wall surface at the ends.

5. Accumulator according to claim 1, **characterised in that** the wall section, inside either end, comprises rough grooves or threads over a first distance, to which a metal or composite insert or sleeve is arranged, the insert or sleeve has adapted external rough grooves or threads on the outside over said first distance and finer threads is arranged, matching end cap threads, on the inside over a second distance shorter than the first distance.

6. Accumulator according to claim 1, **characterised in that** the accumulator comprises end caps having a concave surface toward the accumulator chamber, the shape of the concavity and the material properties of the end caps are adapted such that the end cap expands similarly as the wall section as the pressure varies and preferably seals are arranged outside the periphery of the concavity, sealing between the end cap and either the wall part, a gas tight liner or an insert.

7. Accumulator according to claim 6, **characterised in that** the concavity is in cross section in the form of a circle or ellipse section, the tangent angle or angle of intersection of which exceed 30° from a hypothetical flat bottom of said concave end cap face.

8. Accumulator according to claim 1, **characterised in that** the piston comprises a magnet or other means facilitating detection of piston position using sensors, such as Hall effect sensors, from outside the wall part.

Patentansprüche

1. Speicher (8) zum Speichern und Liefern von hydraulischer Energie, umfassend eine zylindrische Speicherkammer innerhalb eines Wandteils (3) und ein oder zwei Endabschnitte (1), einen Kolben (4), welcher in der Speicherkammer angeordnet ist, und zumindest eine Dichtung (6, 7), welche zwischen dem Kolben (4) und dem Wandteil (3) angeordnet ist, wobei der Kolben (4) mit der Dichtung (6, 7) eine Dimension aufweist, um in die Speicherkammer zu passen, wobei er die Speicherkammer in zwei Teile (C1, C2) teilt, wobei das Wandteil (3) aus einem Kompositmaterial hergestellt ist, **dadurch gekennzeichnet, dass** der Kolben (4) konkave Endoberflächen (4a, 4b) aufweist, welche jeweils dem entsprechenden Speicherkammerteil (C1, C2) zugewandt sind, wobei die Form der Konkavität und die Materialeigenschaften des Kolbens (4) so angepasst sind, dass der Kolben (4) sich ähnlich wie der Wandabschnitt (3) ausdehnt, wenn der Druck sich ändert, so dass der Kolben (4) mit der Dichtung (6, 7) die Speicherkammerteile (C1, C2) dichtend trennt, auch wenn der Druck deutlich variiert, wobei die radiale Dicke des Kolbens Tp nahe der Öffnung der Konkavität und die Wandteildicke Tw, und der Elastizitätsmodul des Kolbenmaterials Ep und des Wandmaterials Ew jeweils so sind, dass ($Tp/Tw \leq Ew/Ep$).

2. Speicher nach Anspruch 1, **dadurch gekennzeichnet, dass** der Kolben aus einem Komposit- oder Polymermaterial hergestellt ist.

3. Speicher nach Anspruch 1, **dadurch gekennzeichnet, dass** die Konkavität der Endflächen des Kolbens in der Form eines Kreises oder eines Ellipsenabschnitts, oder eines Ball- oder Ellipsoidabschnitts ist, wobei dessen Tangentenwinkel oder Schnittwinkel von einem hypothetisch flachen Boden der konkaven Endfläche 30° übersteigt.

4. Speicher nach Anspruch 1, **dadurch gekennzeichnet, dass** der Speicher zwei Endabschnitte in Form von Endkappen aufweist, welche aus einem Kompositmaterial oder metallischen Material, wie Edelstahl, hergestellt sind, wobei vorzugsweise jede der Endkappen eine Durchgangsöffnung für ein Fluid aufweist, wobei vorzugsweise jede der Endkappen mit einem Gewinde versehen ist und das Wandteil korrespondierende Gewinde entweder in einem Einsatz oder in der inneren Wandoberflächen an den Enden umfasst.

5. Speicher nach Anspruch 1, **dadurch gekennzeichnet, dass** der Wandabschnitt, innerhalb jeden Endes, raue Rillen oder Gewinde auf der Außenseite über eine erste Strecke aufweist, zu welcher ein Metall- oder Kompositeinsatz oder -Hülse angeordnet ist, wobei der Einsatz oder die Hülse angepasste raue Rillen oder Gewinde auf der Außenseite über die erste Strecke hat, und zu den Endkappengewinden passend feine Gewinde auf einer Innenseite über eine zweite Strecke angeordnet sind, welcher kürzer als die erste Strecke ist.

6. Speicher nach Anspruch 1, **dadurch gekennzeichnet, dass** der Speicher Endkappen mit einer konkaven Oberfläche gegen die Speicherkammer umfasst, wobei die Form der Konkavität und die Materialeigenschaften der Endkappen so angepasst sind, dass die Endkappen sich ähnlich wie der Wandabschnitt ausdehnen, wenn sich der Druck verändert, und vorzugsweise Dichtungen außerhalb

eines Umfangs der Konkavität angeordnet sind, welche zwischen der Endkappe und entweder dem Wandteil, einem gasdichten Liner oder einem Einsatz dichten.

7. Speicher nach Anspruch 6, **dadurch gekennzeichnet, dass** die Konkavität im Querschnitt in der Form eines Kreis oder Ellipsenabschnitts ist, wobei dessen Tangentenwinkel oder ein Schnittwinkel von einer hypothetisch flachen Bodenfläche der konkaven Endkappenfläche 30° übersteigt.

8. Speicher nach Anspruch 1, **dadurch gekennzeichnet, dass** der Kolben einen Magneten oder andere Mittel umfasst, welche ein Erkennen der Kolbenposition durch Verwenden von Sensoren, wie einem Halleffektsensor, von einer Außenseite des Wandteils erleichtert.

Revendications

1. Accumulateur (8) pour le stockage et la distribution d'énergie hydraulique, comprenant une chambre d'accumulateur cylindrique à l'intérieur d'une partie paroi (3) et une ou deux sections d'extrémité (1), un piston (4) agencé dans la chambre d'accumulateur et au moins un joint (6, 7) agencé entre le piston (4) et la partie paroi (3), le piston (4) avec le joint (6, 7) a une dimension pour se loger dans la chambre d'accumulateur divisant la chambre d'accumulateur en deux parties (C1, C2), la partie paroi (3) se compose d'un matériau composite, **caractérisé en ce que** le piston (4) comporte des surfaces d'extrémité concaves (4a, 4b) faisant face à chaque partie de chambre d'accumulateur respective (C1, C2), la forme de la concavité et les propriétés de matériau du piston (4) sont adaptées de telle sorte que le piston (4) s'étende de façon similaire à la section paroi (3) quand la pression varie, de telle sorte que le piston (4) avec le joint (6, 7) sépare les parties de chambre d'accumulateur (C1, C2) de façon étanche même si la pression varie considérablement, dans lequel l'épaisseur radiale du piston Tp près de l'ouverture de ladite concavité et l'épaisseur de partie paroi Tw, et le module d'élasticité du matériau de piston Ep et du matériau de paroi EW, respectivement, sont tels que $(Tp/Tw \leq Ew/Ep)$.

2. Accumulateur selon la revendication 1, **caractérisé en ce que** le piston se compose d'un matériau composite ou polymère.

3. Accumulateur selon la revendication 1, **caractérisé en ce que** la concavité des faces d'extrémité du piston se présente sous la forme d'une section en cercle ou en ellipse, ou d'une section en bille ou en ellipsoïde, dont l'angle tangent ou l'angle d'intersection dépasse 30°, par rapport à un fond plat hypothétique de ladite face d'extrémité concave.

4. Accumulateur selon la revendication 1, **caractérisé en ce que** l'accumulateur comprend deux sections d'extrémité sous la forme de chapeaux d'extrémité composés d'un matériau composite ou d'un matériau métallique tels que l'acier inoxydable, de préférence chaque chapeau d'extrémité comporte une ouverture débouchante pour le fluide, de préférence chaque chapeau d'extrémité est fileté et la partie paroi comprend des filetages correspondants, soit dans un élément inséré soit dans la surface de paroi intérieure au niveau des extrémités.

5. Accumulateur selon la revendication 1, **caractérisé en ce que** la section de paroi, à l'intérieur de chaque extrémité, comprend des rainures ou filetages approximatifs sur une première distance, sur lesquels un élément inséré ou un manchon métallique ou composite est agencé, l'élément inséré ou manchon a des rainures ou filetages approximatifs externes adaptés sur l'extérieur sur ladite première distance, et des filetages plus minces sont agencés, s'associant aux filetages de chapeau d'extrémité, sur l'intérieur sur une seconde distance plus courte que la première distance.

6. Accumulateur selon la revendication 1, **caractérisé en ce que** l'accumulateur comprend des chapeaux d'extrémité ayant une surface concave vers la chambre d'accumulateur, la forme de la concavité et les propriétés de matériau des chapeaux d'extrémité sont adaptées de telle sorte que le chapeau d'extrémité s'étend de façon similaire à la section de paroi quand la pression varie et de préférence des joints sont agencés à l'extérieur de la périphérie de la concavité, créant une étanchéité entre le chapeau d'extrémité et la partie paroi, une chemise étanche aux gaz ou un élément inséré.

7. Accumulateur selon la revendication 6, **caractérisé en ce que** la concavité se présente, en coupe transversale, sous la forme d'une section en cercle ou en ellipse, dont l'angle tangent ou l'angle d'intersection dépasse 30° par rapport à un fond plat hypothétique de ladite face de chapeau d'extrémité concave.

8. Accumulateur selon la revendication 1, **caractérisé en ce que** le piston comprend un aimant ou un autre moyen facilitant la détection de la position de piston à l'aide de capteurs, tels que des capteurs à effet Hall, depuis l'extérieur de la partie paroi.

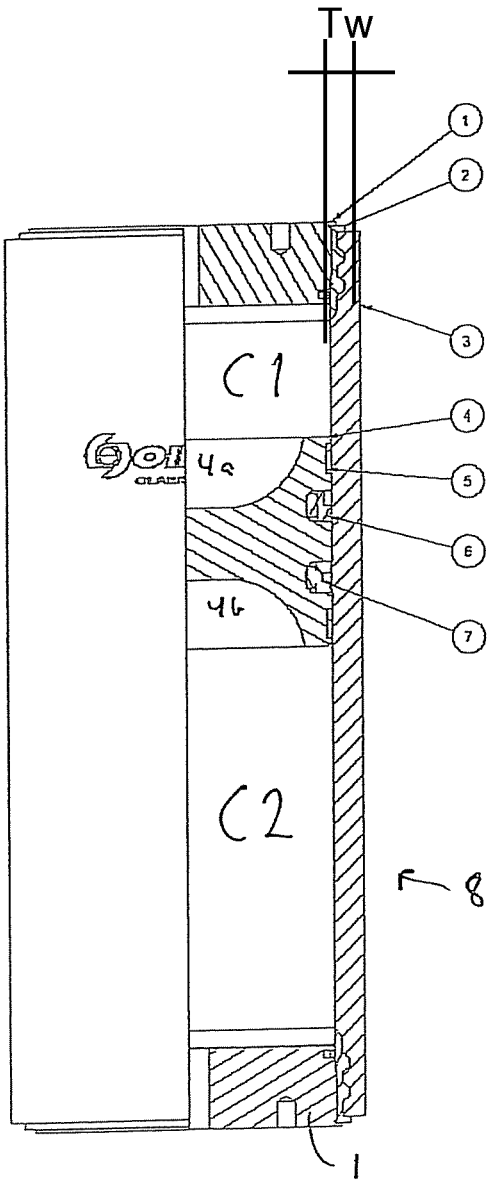


Fig. 1

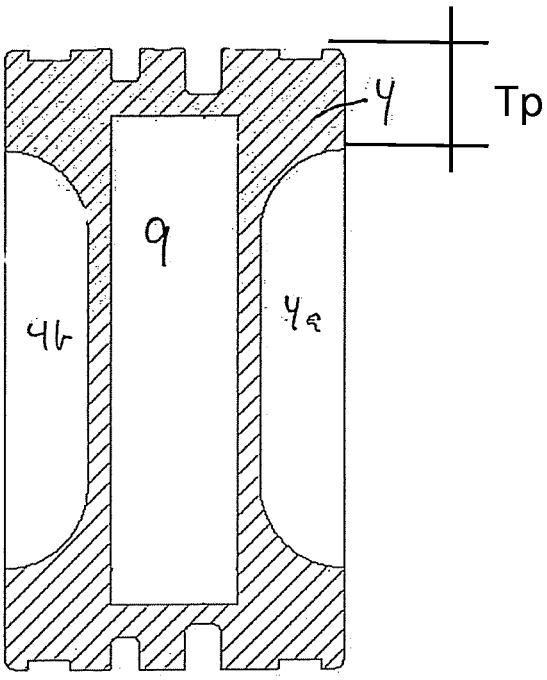


Fig. 2

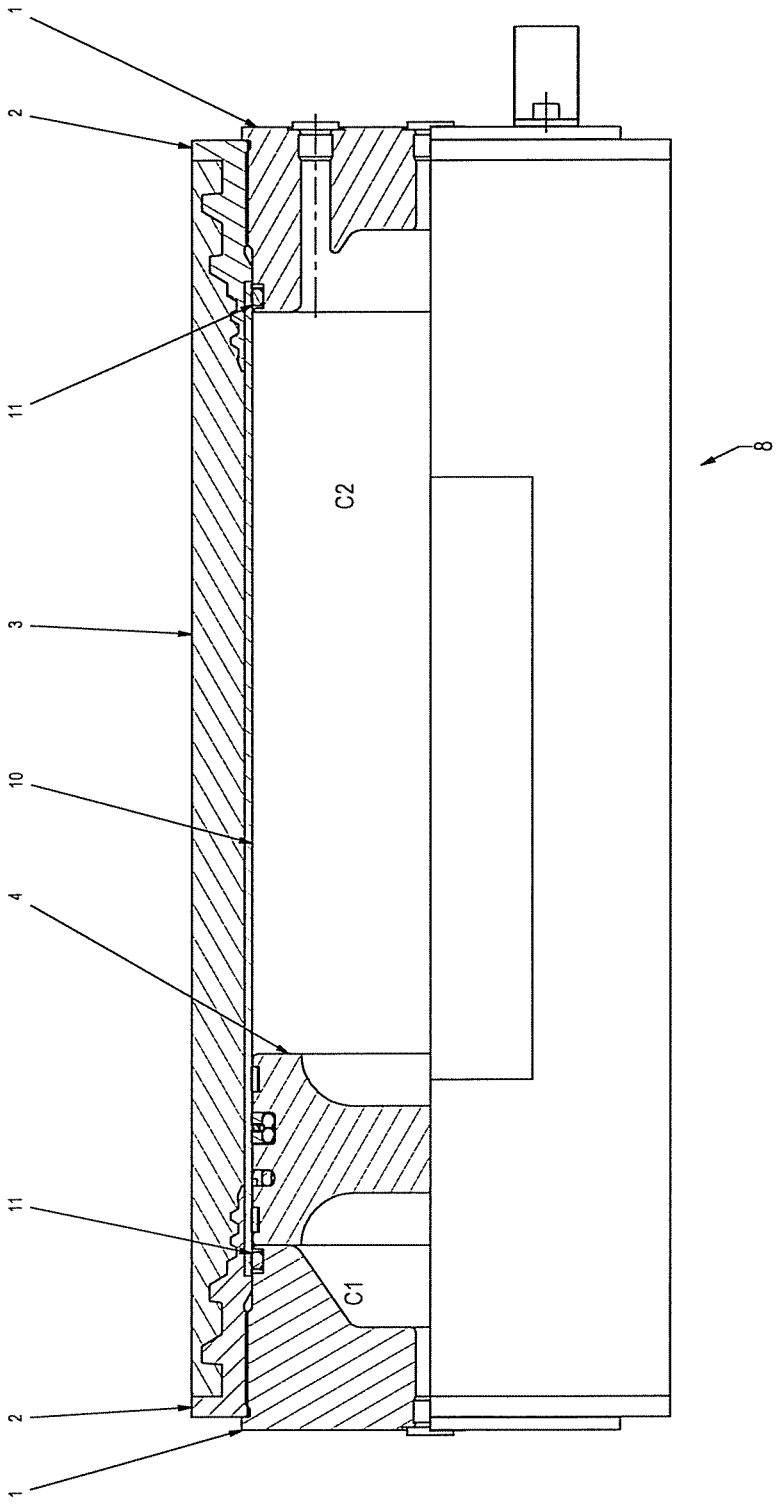


Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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