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(54) **Nyomástartó edény kriogén fluidumok, főként kriogén folyadékok befogadására és tárolására, továbbá eljárás annak előállítására, valamint annak alkalmazása**

116750-9433 SPS

**Pressure vessel for receiving and storing cryogenic fluids, in particular cryogenic liquids, methods for producing said pressure vessel, and use of said pressure vessel**

**Description**

**[0001]** The present invention relates to a pressure vessel for receiving and storing cryogenic fluids, in particular cryogenic liquids, and to a method for producing said pressure vessel and use of said pressure vessel.

**[0002]** Such pressure vessels for storing cryogenic fluids, in particular liquid hydrogen (LH2), which serves as fuel due to its energy efficiency and environmental compatibility, are commonly known. These pressure vessels are composed of a metal vessel that forms a liner and a reinforcement made of fiber-reinforced plastic applied to the liner. Such pressure vessels and/or tanks can be used in all automotive fields, such as aerospace, ship and boat building and in particular in the automobile industry. Such a pressure vessel is described in the document EP-A-2163325.

**[0003]** Liquid hydrogen (LH2) changes into the gaseous state at a temperature of approximately 20 K (-253°C) at atmospheric pressure and is therefore not storable at ambient temperature. In order to allow for high density storage both in the liquid and/or gaseous phase, the hydrogen is stored either at cryogenic temperatures and under the highest possible pressure up to the supercritical state or at temperatures of up to approximately +100°C and also under high pressure. The vessel material must therefore have the highest possible (pressurized) hydrogen resistance and sub-zero toughness. In addition, the pressure vessel and/or tank must be extremely light due to the desired field of application.

**[0004]** The liners of pressure vessels made of fully austenitic steel that have been used in practice until now all have a lack of elastic range as calculated based on Hooke's ratio between the yield strength and the elastic modulus. However, a lower elastic range implies in turn that in order to limit the operational stress of the liner on the elastic range (in order to avoid low cycle fatigue) under the action of the pressure and temperature cycles, a stronger reinforcement made of fiber-reinforced plastic must be used, possibly also in conjunction with an additional intermediate curing to avoid angel hair. This leads to an increase of the weight of the pressure vessels and also increases the unusable volume so that producing the pressure vessels is markedly expensive.

**[0005]** In order to counteract hydrogen embrittlement, DE 10 2007 020 027 A1 proposes plasma nitriding or carburizing a raw container made of an austenitic steel alloy. However, such a plasma nitriding or carburizing has the considerable disadvantage that the non-metallic chemical element in form of dissolved nitrogen or carbon is applied in a way as an additional protection layer on the surface of the austenitic steel alloy, so that martensite may still be formed in the austenitic matrix. Under the influence of hydrogen and of the prevailing cryogenic temperature, the martensite causes embrittlement and is therefore undesirable.

**[0006]** The object of the present invention is therefore to provide a pressure vessel for receiving and storing liquids, particularly cryogenic fluids, by means of which the aforementioned disadvantages can be prevented, is therefore structurally particularly simple, at the same time compact and stable as well as very lightweight, has an enlarged elastic range and a high (pressurized) hydrogen resistance as well as suitability to cryogenic temperatures and is very cost-effective to produce, and to facilitate a method for its production and its use.

**[0007]** This objective is achieved in a surprisingly simple manner by the features of claim 1.

[0008] The design of the pressure vessel in accordance with the invention for receiving and storing cryogenic fluids, in particular cryogenic liquids, which is composed of a metal vessel that forms a liner and a reinforcement made of fiber-reinforced plastic applied to the liner, wherein the liner is made of a non-magnetic metal alloy having a fully austenitic face-centered cubic lattice structure and, in order to enlarge and/or increase the elastic range and/or to increase the yield strength prior to applying the reinforcement made of fiber-reinforced plastic, is subjected to a nitriding treatment by means of nitrogen or ammonia provides a particularly simple, compact and stable construction of a relatively light-weight pressure vessel. At the same time, the pressure vessel in accordance with the invention has an enlarged, markedly high elastic range. On the one hand, the elastic range of liners made of a non-magnetic metal alloy having a fully austenitic face-centered cubic lattice structure, already significantly increases, per se, as the temperature drops, so that at cryogenic temperatures, the elastic range of liners made of aluminum alloys is attained or even exceeded, even though the elastic range of the former at ambient temperature lies significantly lower than that of the latter, approximately in the range of 50%. On the other hand, the nitriding treatment itself allows for an additional increase of the yield strength at a constant elastic modulus, the quotient of which results in such an increased elastic range. These alloying techniques allow additionally increasing the nitrogen content, which in turn may be increased by high chromium and manganese contents and by adding niobium, if required, and consequently the elastic range and the yield strength of the liner. The solubility of nitrogen in fully austenitic steels can also be raised in particular by way of the alloying elements nickel, vanadium and molybdenum. When using nickel, an amount of at least 13% is preferable in order to guarantee a fully austenitic state. All this makes it possible to ensure a high (pressurized) hydrogen resistance and to reliably limit or avoid a cryogenic temperature embrittlement. Lastly the production of the vessel in accordance with the invention is simple, less labour-intensive and thus extremely cost-effective.

[0009] The liner is treated by means of nitrogen or ammonia at a temperature above approximately 1,000°C, in particular in a temperature range between approximately 1,000 and approximately 1,200°C. Consequently, the nitriding treatment is carried out at the temperature of solution annealing of the material of the liner. Hereby, the nitrogen can be entirely solubilized. In addition, the formation of brittle phases, such as the sigma phase, the chi phase or the chromium nitride phase, and as a consequence thereof the formation of embrittling nitrides, which form at nitriding temperatures of below approximately 1,050°C, can thus be avoided. In addition, the diffusion rate at temperatures above approximately 1,050°C is so high that with typical liner wall thicknesses of approximately 1.0 mm, a total alloying with nitrogen is possible within a commercially reasonable time-frame.

[0010] As a result, the pressure vessel in accordance with the invention has a multitude of benefits. The liner still consists of a non-magnetic metal alloy with a fully austenitic face-centered cubic lattice structure after a nitriding treatment has been carried out. That way the high initial yield strength of the non-magnetic metal alloy with a fully austenitic face-centered cubic lattice structure prior to the nitriding treatment is advantageously used. With an additional nitriding treatment, a high yield strength $R_{p0,2}$ of at least 800 MPa or more can be easily achieved. In turn, a high yield strength $R_{p0,2}$ has an advantageous effect on a highest possible elastic range $\varepsilon$ according to Hooke ($\varepsilon = R_{p0,2} / E$).

[0011] Further advantageous details of the vessel in accordance with the invention are described in claims 2 to 11.

[0012] The constructional measures of claim 2, according to which the liner is composed of mangalloy, are particularly important. The mangalloy used as a material for the liner according to the invention is a full austenite, i.e., a steel with a fully austenitic lattice structure, that is adapted for use at cryogenic temperatures, has a good (pressurized) hydrogen resistance and whose elastic range is enlarged by a nitriding treatment in its material properties and thus has an elastic range that is increased as a function of the nitriding degree.

[0013] This can be achieved in a particularly advantageous manner through the features of claim 3, according to which the liner is composed of a metal alloy 1.3914, 1.3948, 1.3952, 1.3957, 1.3964, 1.3965, 1.3974, 1.4529, 1.4547, 1.4565, 1.4566, Nitronic 50, S20910, 22-13-5, XM-19, 1.4652, 1.4659 or 27-7 Mo.

[0014] According to the features of claim 4 of the invention, the liner in accordance with the invention is joined from at least two separate components to be welded together forming a metal vessel.

[0015] It is also within the framework of the invention to subject the liner, partially or fully, i.e., only locally or in its entirety, to the nitriding treatment by means of nitrogen or ammonia, in accordance with claim 5.

[0016] In accordance with the features of claim 6, the liner is subjected to the nitriding treatment by means of nitrogen or ammonia after welding. Since the weld seams must have mechanical properties that are similar to those of the metal alloy of the liner, the effects of segregations on mechanical properties and on the assurance of a fully austenitic state can be compensated for. Local softening and evaporation of alloy elements, in particular of nitrogen and manganese, due to welding heat can thus be compensated for after welding.

[0017] According to claim 7, the liner, after the nitriding treatment, is advantageously quenched by means of high-pressure quick cooling, in particular with nitrogen or argon. A sufficiently fast cooling from the temperature of the solution-annealing allows maintaining the introduced nitrogen in the solute state.

[0018] The features of claim 8, according to which the liner is, in particular partially or fully, i.e., merely locally or in its entirety, cold-drawn by an amount of up to approximately 25%, in particular of less than approximately 15%, prior to applying the reinforcement made of fiber-reinforced plastic, is of particular interest with regard to a further increase of the elastic range and of the yield strength. As compared to liners made of an aluminum alloy, the coefficient of enlargement of the elastic range through plastic deformation (drawing) is doubled or even tripled. From this it follows that with liners made of a non-magnetic metal alloy with a fully austenitic face-centered cubic lattice structure, cold deformation already leads to a significant increase of the elastic range at a low degree of deformation. As a matter of fact, cold drawing additionally even leads to a lowering of the elastic modulus, thus resulting in a doubly advantageous effect on the increase of the quotient. In addition, the higher the nitrogen content in the material, respectively in the metal alloy of the liner, the more efficient the cold reduction according to the invention becomes. When provided with high nitrogen content, the cold reduction thus already starts at a higher yield strength level and increases with a steeper gradient.

[0019] In this context, it is particularly advantageous that the liner is cold-drawn before or after the nitriding treatment by means of nitrogen or ammonia, in accordance with claim 9.

[0020] It also lies within the framework of the invention that the liner is solution-annealed, in particular partially or fully, i.e., merely locally or in its entirety, before being cold-drawn, in accordance with claim 10.

[0021] Claim 11 of the invention provides that the liner is preferably tempered, in particular partially or fully, i.e., merely locally or in its entirety, after being cold-drawn. In addition to reducing residual stresses, tempering leads to an additional increase of the yield strength on the one hand and to the enlargement of the elastic range on the other hand or, conversely, to a reduction of the required degree of stretching, respectively.

[0022] This objective is achieved, with regard to a method, in a surprisingly simple manner by the features of claim 12.

[0023] The embodiment of the method according to the invention for producing a pressure vessel for cryogenic fluids, composed of a metal vessel that forms a liner and a reinforcement made of fiber-reinforced plastic applied to the liner, wherein the liner is made of a non-magnetic metal alloy having a fully austenitic face-centered cubic lattice structure and, prior to applying the reinforcement made of fiber-reinforced plastic, is subjected to a nitriding treatment by means of nitrogen or ammonia in order to enlarge and/or increase the elastic range and/or to increase the yield strength, has proven particularly advantageous in practice, in addition to the advantages already described with regard to the pressure vessel according to the invention, which also comprises the method according to the invention.

[0024] Further advantageous details of the method in accordance with the invention are described in claims 13 to 24.

[0025] According to claim 13, the liner is very advantageously composed of a mangalloy.

[0026] In this context, the liner is preferably made of the metal alloy 1.3914, 1.3948, 1.3952, 1.3957, 1.3964, 1.3965, 1.3974, 1.4529, 1.4547, 1.4565, 1.4566, Nitronic 50, S20910, 22-13-5, XM-19, 1.4652, 1.4659 or 27-7 Mo, in accordance with claim 14.

[0027] It additionally lies within the framework of the invention that the liner is joined from at least two separate components to be welded together to form a metal vessel in accordance with claim 15.

[0028] In addition, the invention according to the measures of claim 16 provides that the liner is partially or fully subjected to the nitriding treatment by means of nitrogen or ammonia.

[0029] According to the invention, the liner is treated by means of nitrogen or ammonia at a temperature above approximately 1,000°C, in particular in a temperature range between approximately 1,000 and approximately 1,200°C.

[0030] According to the measures of claim 17, the liner, after the nitriding treatment, is preferably quenched by means of high-pressure quick cooling, in particular with nitrogen or argon.

[0031] In accordance with the process measures of claim 18, the liner can be subjected to a nitriding treatment by means of nitrogen or ammonia after welding, in order to increase the nitrogen content and thus the elastic range and the yield strength of the liner itself.

[0032] The features of claim 19, namely that the liner is, in particular partially or fully, cold-drawn by an amount of up to approximately 25%, in particular of less than approximately 15%, prior to applying the reinforcement made of fiber-reinforced plastic, are of particular importance for the method according to the invention.

[0033] In this context it is additionally advantageous to cold-draw the liner before or after the nitriding treatment by means of nitrogen or ammonia, in accordance with claim 20.

[0034] According to claim 21, it additionally lies within the framework of the invention that the blank of the liner is pressed for example onto a mold or die by constant pressure from the hydraulic or pneumatic pressure medium. During cold drawing, the liner of the pressure vessel configured according to the invention is, in a way, "blown" into the mold or die, so that at an initially constant feed rate of the hydraulic or pneumatic pressure medium, its pressure is very strongly increased when the liner starts to rest on the mold and/or the die, respectively, when the liner is continuously pressed further onto the mold and/or die. Consequently, a simple pressure limitation can be used as a switch-off criterion.

[0035] In addition, cold drawing by so-called "inflation" at a lowered temperature, i.e., for practical reasons for example by means of liquid nitrogen, significantly improves the deformability of the liner of the pressure vessel according to the invention because of the homogenization of the deformation known in fully austenitic face-centered cubic materials and of the consequently increased maximally possible degree of deformation.

[0036] According to claim 22, the invention additionally provides that the liner is, in particular partially or fully, subjected to solution-annealing before being cold-drawn.

[0037] According to the measures of claim 23, the liner is, in particular partially or fully, subjected to tempering after being cold-drawn.

[0038] Finally, it also lies within the framework of the invention to use the pressure vessel in accordance with the invention for receiving and storing fluids, in particular cryogenic fluids, preferably oxygen and hydrogen, in vehicles, in particular in aerodynes or aircraft for application in aeronautics, preferably in aeroplanes and space aerodynes, in particular in water vehicles, preferably a submarine or air cushion craft (Hovercraft), or in particular in land vehicles, preferably in a motor car, people transport vehicle, such as a bus or van, truck or camper van, in accordance with claim 24. The pressure vessel according to the invention is particularly suited for hydrogen tanks of power-driven vehicles, rocket fuel tanks, satellite tanks or high pressure tanks, in particular high pressure gas tanks, for example for helium, preferably as complete tanks stored in liquid hydrogen, wherein the extremely low temperature allows for a reduction of the volume of the high pressure tank.

[0039] Other features, advantages and details of the invention can be gathered from the following description of a preferred embodiment of the invention and based on the drawing. Here, the

Fig. shows a schematic lengthwise section view through an embodiment of a pressure vessel shaped in accordance with the invention.

[0040] The pressure vessel 10 in accordance with the invention for receiving and storing liquids, particularly cryogenic fluids, preferably oxygen and hydrogen, is used in an advantageous manner in vehicles, particularly in aerodynes or aircraft for application in aeronautics, preferably in aeroplanes and space aerodynes, particularly in water vehicles, preferably in a submarine or air cushion craft (Hovercraft), or particularly in land vehicles, preferably in a passenger vehicle, people transport vehicle, such as a bus or van, truck or camper van. The pressure vessel 10 according to the invention is particularly suited for use as a hydrogen tank of a power-driven vehicle or a rocket fuel tank or satellite tank of an aerodyne for application in aeronautics or a high pressure tank or high pressure gas tank. The pressure vessel 10 in accordance with the invention is suitable for use in particular as a high pressure gas tank, for example for helium, preferably as complete tanks stored in liquid hydrogen, wherein the extremely low temperature allows for a reduction of the volume of the high pressure gas tank.

[0041] The embodiment of the vessel 10 according to the invention shown schematically in the Fig. comprises a metal vessel that forms a liner 12 and a reinforcement 14 made of fiber-reinforced plastic applied to the liner 12.

[0042] As can be seen in the Fig., the liner 12 has a substantially cylindrical section 16. Dome-shaped sections 22 and 24 are adjacent to the respective ends 18 and 20 of the cylindrical section 16. These sections can be integrally formed with or welded onto the cylindrical section 16. A bottle head 26 (not shown) can be integrated, for example also welded, onto at least one of the dome-shaped sections 22 or 24.

[0043] It is known that metals and metal alloys that are frequently or even permanently exposed to hydrogen are subjected to embrittlement. A measure thereof is the so-called embrittlement index, which however does not allow predicting the actual material properties during use, since the breaking strength of a material in a (pressurized) hydrogen environment is influenced by a variety of factors, such as the hydrogen gas pressure, the temperature and the tensile stress. Therefore, when choosing suitable alloys for a hydrogen tank liner, all properties relevant to a specific application must be taken into account.

[0044] In addition to the (pressurized) hydrogen compatibility and the suitability for use at cryogenic temperatures, the most important selection criteria are the enlarged elastic range and high yield strength. These properties must be largely stable in a temperature range of approximately 4 K to approximately 400 K and at pressures of up to approximately 700 bar.

[0045] The liner 12 in accordance with the invention is composed of a non-magnetic metal alloy with a fully austenitic face-centered cubic lattice structure and is more specifically made of mangalloy, preferably of the metal alloy 1.3914, 1.3948, 1.3952, 1.3957, 1.3964, 1.3965, 1.3974, 1.4529, 1.4547, 1.4565, 1.4566, Nitronic 50, S20910, 22-13-5, XM-19, 1.4652, 1.4659 or 27-7 Mo.

[0046] The pressure vessel 10 in accordance with the invention is manufactured in the usual manner from the afore-mentioned materials, respectively assembled and/or welded from pre-fabricated components (for example the cylindrical section 16 and the dome-shaped sections 22, 24). As an alternative, it is also conceivable to provide a seamlessly formed liner 12. At least one bottle head 26 for filling and emptying can be integrated into suitable sections of the pressure vessel 10.

[0047] Prior to applying the reinforcement 14 made of fiber-reinforced plastic, the liner 12 is particularly advantageously subjected to a nitriding treatment by means of nitrogen or ammonia. That way, the nitrogen content and thus the elastic range and the yield strength of the liner 12 itself are increased. In doing so, the geometry of the liner 12 remains unchanged.

[0048] In this connection, the liner 12 can be partially or fully subjected to the nitriding treatment by means of nitrogen or ammonia.

[0049] In this context, it is particularly advantageous that the liner is treated, in particular partially or fully, by means of nitrogen or ammonia at a temperature above approximately 1,000°C. The nitriding treatment preferably takes place in a temperature range between approximately 1,000 and approximately 1,200°C in a nitrogen or ammonia atmosphere with a suitable nitrogen or ammonia pressure, respectively. Consequently, the nitriding treatment takes place in a solution-annealing temperature range.

[0050] After the nitriding treatment, the liner 12 is quenched by means of high-pressure quick cooling, in particular with nitrogen or argon.

[0051] The nitriding treatment is preferably carried out after welding.

[0052] Additionally, in accordance with provided process measures, the liner 12 can be preferably, in particular partially or fully, cold-drawn by an amount of up to approximately 25%, in particular of less than approximately 15%, prior to applying the reinforcement made of fiber-reinforced plastic.

[0053] Prior to cold drawing, the liner 12 and/or a blank (not shown) of the liner 12 can preferably be subjected to solution-annealing.

[0054] For cold drawing, the blank of the liner 12, which is smaller in terms of shape and measurements than the liner 12 to be produced, is placed into a mold or die (not shown). The blank of the liner 12 is then exposed to a hydraulic or pneumatic pressure medium, which is applied onto the interior 28 of the liner 12. The hydraulic or pneumatic pressure medium deforms, in a way "inflates", the blank of the liner 12 in order to form the liner 12, whose shape and measurements correspond to those of the mold or die. In doing so, the blank of the liner 12 to be deformed at least comes to rest on the mold or die and/or, beyond that, is further pressed against the mold or die. In the process, the liner 12 is cold-drawn by an amount of up to approximately 25%, in particular of less than approximately 15%.

[0055] Finally, the liner 12 is removed from the mold or die.

[0056] After cold drawing, the liner 12 is preferably subjected to tempering. In addition to reducing residual stresses, tempering leads to an additional increase of the stretching parameters or, conversely, to a reduction of the required degree of stretching, respectively. The effect of tempering can be interpreted as strain ageing and/or as blocking of dislocations, introduced by the cold drawing process, by way of nitrogen atoms. The higher the degree of cold forming and the higher the nitrogen content, the more the elastic range is enlarged. The following table shows an overview of the material properties before and after cold drawing.

[0057] Thereafter, the reinforcement 14 of the pressure vessel 10 according to the invention is wound under a suitable pre-tension.

[0058] The reinforcement 14 of the pressure vessel 10 according to the invention is made of a fiber-reinforced composite. The reinforcement 14 rests under tension on the liner 12 made of the metal alloy defined above for the present invention. In the case shown here, the liner 12 completely covers the reinforcement 14.

[0059] The pressure vessel 10 can be fitted with the fiber composite in a wet-winding process and resin infiltration process. The important thing is that, in its hardened state, the fiber composite forming the outer wall rests on the liner 12 forming the inner wall under tension. Pre-impregnated fiber bundles or strands, so called rovings, can be used. However, the process for forming the fiber-reinforced plastic on the liner 12 should not be limited to the wet-winding process. For instance, it is also possible to use a prepreg winding process or a single strand winding process.

[0060] The fibers are preferably carbon, glass, basalt, aramid and/or ceramic fibers, but are not limited thereto. Rather, all thermally and mechanically highly resistant fibers can be used. Besides glass fibers, basalt fibers have the advantage of a distinctly positive expansion coefficient and consequently allow for a reduction of the difference to the thermal expansion coefficient of the liner 12.

[0061] Although polyurethane resins are suitable, epoxy resins are mainly used because of their thermosetting behavior and their better processability. However, using resin mixtures, for example of polyurethane and epoxy resin, is also conceivable.

[0062] The choice of material for the liner 12 and the nitriding treatment thereof allows providing a pressure vessel 10 having an improved suitability for storage of liquid and/or gaseous hydrogen, because of its high pressure hydrogen tolerance and because of its suitability for cryogenic temperatures. At the same time, requirements regarding rigidity and the elastic range as well as requirements regarding buckling behavior and lightweight construction are optimally met.

[0063] The present invention is not limited to the shown embodiment of the liner 12. For instance, it is readily possible to join two cylinders of half the total length having respectively integrally formed domes, which are produced for example by way of a suitable deformation technology, such as flow-forming, of a suitably formed blank, with the liner 12 via a welding seal located in the middle of the length of the pressure vessel. Spherical pressure vessels or pressure vessels with any other rotationally symmetric and/or not rotationally symmetric shape are also possible. For example, the dome-shaped sections 22 can be formed in the shape of a hemisphere, of a spherical cap, of a calotte, of a calotte of an ellipsoid, of a cone, of an ellipse, of a cassinian oval, of a half torus or with other suchlike cross-sectional shapes.

[0064] Moreover, it is fundamentally also conceivable to carry out the nitriding treatment only after (partial or full) cold drawing. Any other embodiments of the method according to the invention, which provide cold drawing and/or nitriding in a variety of chronological orders and are also included in and covered by the teaching of the invention, are exemplarily mentioned in the following table.

Table

| Nitriding I | Nitriding II | Nitriding + Cold drawing I | Nitriding + Cold drawing II | Nitriding + Cold drawing III |
|---|---|---|---|---|
| Manufacturing component parts and welding to the liner | Manufacturing component parts and welding to liner halves | Manufacturing component parts and welding to liner halves | Manufacturing component parts and welding to liner halves | Manufacturing component parts and welding to liner halves |
| Nitriding of the liner | Nitriding of the liner halves | Nitriding of the liner halves | Nitriding of the liner halves | Nitriding of the liner halves |
| | Welding to the liner | Welding to the liner (smaller seam-0) | Welding to the liner (smaller seam-0) | Welding to the liner |
| | Local nitriding of the assembly welding seam | Local cold drawing of the seam | Local nitriding of the assembly welding seam | Local nitriding of the assembly welding seam |
| | | (Tempering) | Local cold drawing of the seam | Global cold drawing |
| | | | (Tempering) | (Tempering) |

NYOMÁSTARTÓ EDÉNY KRIOGÉN FLUIDUMOK, FŐKÉNT KRIOGÉN FOLYADÉKOK BEFOGADÁSÁRA ÉS TÁROLÁSÁRA, TOVÁBBÁ ELJÁRÁS ANNAK ELŐÁLLÍTÁSÁRA, VALAMINT ANNAK ALKALMAZÁSA

*Szabadalmi igénypontok*

1. Nyomástartó edény kriogén fluidumok, főként kriogén folyadékok befogadására és tárolására, amely nyomástartó edény egy bélésréteget (12) képező fémtartályból és a bélésrétegre (12) felvitt, szálerősítésű műanyagból készült merevítésből (14) áll, **azzal jellemezve**, hogy a bélésréteg (12) egy nemmágneses, teljesen ausztenites, lapcentrált-köbös rácsszerkezetű fémötvözetből van készítve és a legalább 800 MPa vagy annál nagyobb $R_{p0,2}$ folyási határ növeléséhez a szálerősítésű műanyagból lévő merevítés (14) felvitele előtt nitrogén vagy ammónia révén 1000°C-nál nagyobb hőmérsékleten, főként egy 1000 és 1200°C közötti hőmérséklet-tartományban nitridáló kezelésnek van alávetve.

2. Az 1. igénypont szerinti nyomástartó edény, **azzal jellemezve**, hogy a bélésréteg (12) tengeralattjáró-acélból van készítve.

3. Az 1. vagy 2. igénypont szerinti nyomástartó edény, **azzal jellemezve**, hogy a bélésréteg (12) 1.3914, 1.3948, 1.3952, 1.3957, 1.3964, 1.3965, 1.3974, 1.4529, 1.4547, 1.4565, 1.4566, Nitronic 50, S20910, 22-13-5, XM-19, 1.4652, 1.4659 vagy 27-7 Mo fémötvözetből van készítve.

4. Az 1-3. igénypontok bármelyike szerinti nyomástartó edény, **azzal jellemezve**, hogy a bélésréteg (12) legalább két egymással összehegesztendő önálló részből van egy fémtartállyá összeillesztve.

5. Az 1-4. igénypontok bármelyike szerinti nyomástartó edény, **azzal jellemezve**, hogy a bélésréteg (12) részben vagy teljesen alá van vetve a nitrogén vagy ammónia általi nitridáló kezelésnek.

6. Az 1-5. igénypontok bármelyike szerinti nyomástartó edény, **azzal jellemezve**, hogy a bélésréteg (12) a hegesztés után van a nitrogén vagy ammónia általi nitridáló kezelésnek alávetve.

7. Az 1-6. igénypontok bármelyike szerinti nyomástartó edény, **azzal jellemezve**, hogy a bélésréteg (12) a nitridáló kezelés után nagynyomású gyorshűtéssel, főként nitrogén vagy argon általi gyorshűtéssel van edzve.

8. Az 1-7. igénypontok bármelyike szerinti nyomástartó edény, **azzal jellemezve**, hogy a bélésréteg (12), főként részben vagy teljesen, a szálerősítésű műanyagból készült merevítés (14) felvitele előtt mintegy 25% mértékben, főként kisebb, mint kb. 15% mértékben hidegen van nyújtva.

9. A 8. igénypont szerinti nyomástartó edény, **azzal jellemezve**, hogy a bélésréteg (12) a nitrogén vagy ammónia általi nitridáló kezelés előtt vagy után van hidegen nyújtva.

10. Az 1-9. igénypontok bármelyike szerinti nyomástartó edény, **azzal jellemezve**, hogy a bélésréteg (12), főként részben vagy teljesen, a hidegnyújtás előtt oldó izzításnak van alávetve.

11. Az 1-10. igénypontok bármelyike szerinti nyomástartó edény, **azzal jellemezve**, hogy a bélésréteg (12), főként részben vagy teljesen, a hidegnyújtás után meg van eresztve.

12. Eljárás nyomástartó edény előállítására kriogén folyadékok számára, amely nyomástartó edény egy bélésréteget (12) képező fémtartályból és a bélésrétegre (12) felvitt, szálerősítésű műanyagból készült merevítésből (14) áll, főként az előző igénypontok bármelyike szerint, **azzal jellemezve**, hogy a bélésréteget (12) egy nemmágneses, teljesen ausztenites, lapcentrált-köbös rácsszerkezetű fémötvözetből készítjük és a legalább 800 MPa vagy annál nagyobb $R_{p0,2}$ folyási határ növeléséhez a szálerősítésű műanyagból levő

merevítés (14) felvitele előtt nitrogén vagy ammónia révén 1000°C-nál nagyobb hőmérsékleten, főként egy 1000 és 1200°C közötti hőmérséklet-tartományban nitridáló kezelésnek vetjük alá.

13. A 12. igénypont szerinti eljárás, **azzal jellemezve**, hogy a bélésréteget (12) tengeralattjáró-acélból készítjük.

14. A 12. vagy 13 igénypont szerinti eljárás, **azzal jellemezve**, hogy a bélésréteget (12) 1.3914, 1.3948, 1.3952, 1.3957, 1.3964, 1.3965, 1.3974, 1.4529, 1.4547, 1.4565, 1.4566, Nitronic 50, S20910, 22-13-5, XM-19, 1.4652, 1.4659 vagy 27-7 Mo fémötvözetből készítjük.

15. A 12-14. igénypontok bármelyike szerinti eljárás, **azzal jellemezve**, hogy a bélésréteget (12) legalább két egymással összehegesztendő önálló részből illesztjük össze fémtartállyá.

16. A 12-15. igénypontok bármelyike szerinti eljárás, **azzal jellemezve**, hogy a bélésréteget (12) részben vagy teljesen alávetjük a nitrogén vagy ammónia általi nitridáló kezelésnek.

17. A 12-16. igénypontok bármelyike szerinti eljárás, **azzal jellemezve**, hogy a bélésréteget (12) a nitridáló kezelés után nagynyomású gyorshűtéssel, főként nitrogén vagy argon általi gyorshűtéssel edzzük.

18. A 12-17. igénypontok bármelyike szerinti eljárás, **azzal jellemezve**, hogy a bélésréteget (12) a hegesztés után vetjük alá a nitrogén vagy ammónia általi nitridáló kezelésnek.

19. A 12-18. igénypontok bármelyike szerinti eljárás, **azzal jellemezve**, hogy a bélésréteget (12) főként részben vagy teljesen, a szálerősítésű műanyagból készült merevítés (14) felvitele előtt mintegy 25% mértékben, főként kisebb, mint kb. 15% mértékben hidegen nyújtjuk.

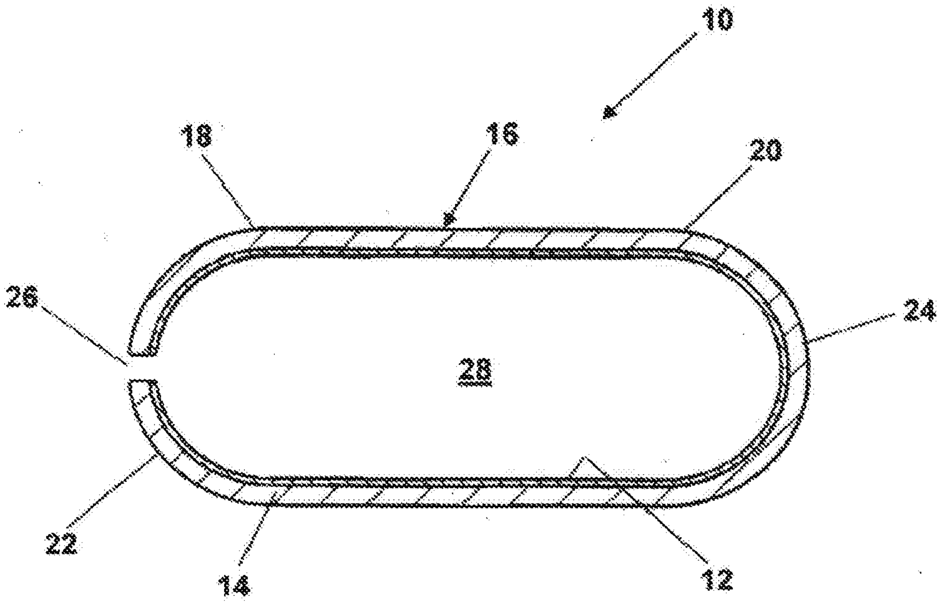
20. A 19. igénypont szerinti eljárás, **azzal jellemezve**, hogy a bélésréteget (12) a nitrogén vagy ammónia általi nitridáló kezelés előtt vagy után hidegen nyújtjuk.

21. A 19. vagy 20. igénypont szerinti eljárás, **azzal jellemezve**, hogy a bélésréteg (12) nyersdarabját a hidraulikus vagy pneumatikus nyomóközeg állandó nyomása által a formára vagy a süllyesztékre rásajtoljuk.

22. A 12-21. igénypontok bármelyike szerinti eljárás, **azzal jellemezve**, hogy a bélésréteget (12) főként részben vagy teljesen, a hidegnyújtás előtt oldó izzításnak vetjük alá.

23. A 12-22. igénypontok bármelyike szerinti eljárás, **azzal jellemezve**, hogy a bélésréteget (12) főként részben vagy teljesen, a hidegnyújtás után megeresztjük.

24. Az 1-11. igénypontok bármelyike szerinti vagy a 12- 23. igénypontok szerinti eljárással előállított nyomástartó edény alkalmazása folyadékok, főként kriogén fluidumok, különösen oxigén és hidrogén befogadására és tárolására járművekben, főként a repülés és az űrhajózás légi járműveiben vagy repülő eszközeiben, előnyösen repülőgépekben és űrjárművekben, adott esetben vízi járművekben, előnyösen tengeralattjáróban vagy légpárnás járműben, vagy adott esetben szárazföldi járművekben, előnyösen személygépkocsiban, személyszállító járműben, mint például buszban vagy kisbuszban, tehergépkocsiban vagy lakókocsiban.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