

SOLID STATE HYDROGEN STORAGE TANK

FIELD OF THE INVENTION

[0001] The present invention relates to a gas storage device. More particularly, the present invention relates to a solid state hydrogen storage tank, using magnesium-based hydrogen alloy powder-based hydrogen storage materials and reactor components to store hydrogen. Embodiments of the present invention relate to the reaction between hydrogen gas and solid storage materials such as metal alloys and composite particles. It involves the storage of solid hydrogen and the subsequent release of gaseous hydrogen.

BACKGROUND OF THE INVENTION

[0002] Hydrogen has received a lot of attention in the past as a potential fuel or fuel additive. The world's oil reserves are rapidly decreasing, but the supply of hydrogen is virtually unlimited. Hydrogen can be extracted from coal, natural gas and other hydrocarbons, or it can be produced by electrolysis of water. Furthermore, hydrogen can be produced through water electrolysis using sustainable energy, eliminating the need for fossil fuels. Although hydrogen is currently more expensive than petroleum, it is a cost-effective fuel. Hydrogen has the highest energy density per unit weight among chemical fuels and is considered environmentally friendly because water is the main byproduct of burning hydrogen.

[0003] Hydrogen has many potential uses as a fuel, but a significant limitation to its application is the lack of suitable hydrogen storage methods. Hydrogen can be stored as a compressed gas at pressures ranging from 300 to 700 bar, but this poses safety issues and requires tanks that can withstand the high pressures. Storing hydrogen as a compressed gas requires the use of fairly large and bulky containers. Additionally, transferring hydrogen is challenging because it is stored in a fairly large container, and the low density of hydrogen also limits the amount of hydrogen that can be contained in the container. Furthermore, it should be noted that these tanks may present safety issues when installed in fuel cells.

[0004] Additionally, due to its highly flammable nature, storing hydrogen in liquid form poses significant safety concerns when used as a fuel for power generation. Liquid hydrogen must be stored at temperatures below -253° C and is highly volatile if spilled. Liquid hydrogen is expensive

to be stored, and the energy required for the liquefaction process accounts for a large portion of the energy consumption.

[0005] Alternatively, some materials and metal alloys can store and release hydrogen in a reversible manner. Due to excellent hydrogen storage efficiency, they are considered to be an excellent hydrogen storage material. Storing hydrogen as a solid hydride provides a higher volumetric storage density than storing it as a compressed gas or liquid in pressure tanks.

[0006] Storing hydrogen as solid hydrides is safer than storing hydrogen in gas or liquid form due to fewer safety issues. Solid metal or alloy systems can absorb hydrogen at high density. Metal hydrides are produced under specified temperature, pressure or chemical conditions to efficiently store large amounts of hydrogen. Commonly used hydrogen storage materials are metal-based (magnesium-based) alloys. The mechanism of hydrogen absorption by hydrogen storage alloys mainly involves the interaction between hydrogen atoms and metal atoms, including: 1. hydrogen absorption and dissociation - hydrogen molecules (H_2) first being absorbed onto the metal surface, where they are dissociated into hydrogen atoms (H); 2. surface diffusion - dissociated hydrogen atoms migrating on the metal surface; 3. getting inside the metal - hydrogen atoms moving from the surface into the interstitial positions of the metal lattice; 4. hydride formation - solid solutions (hydrogen is dissolved in the metal) or compounds (such as metal hydrides) being formed inside the metal as the hydrogen atoms diffuse. When hydrogen storage alloys release hydrogen, the process is essentially the reverse; upon heating, the hydride decomposes, and the hydrogen atoms diffuse outward from the metal lattice and recombine into hydrogen molecules. While the principle is simple, the design of the storage device is critical to controlling the convenient storage and retrieval of hydrogen.

[0007] Heat transfer rates can enhance or hinder the efficient transport of metal alloys used for the hydrogen into and out of the hydride storage systems. When hydrogen is absorbed into the hydrogen storage alloy during the hydrogenation process, an exothermic process occurs. When hydrogen is desorbed from the alloy during the dehydrogenation process, an endothermic reaction occurs. Transferring heat within these systems or controlling the desired temperature distribution throughout the volume of the storage material is key in metal alloy metal hydride hydrogen storage systems. Release of hydrogen from the crystal structure of a metal hydride generally requires a certain amount of energy input in the form of heat. Hydrogen in the crystal structure of a metal usually results in an exothermic reaction, releasing heat energy.

[0008] The heat generated during the hydrogenation of hydrogen storage materials and metal alloys needs to be dissipated. Insufficient heat dissipation may cause the hydrogenation process to slow down or stop. This is a major issue that hinders fast charging. Fast charging causes the hydrogen storage alloy to rapidly hydride, generating a large amount of heat. Cooling and heating efficiency will affect the rates of hydrogenation and dehydrogenation reactions. Considering the heat input and heat dissipation requirements of these systems, especially large-volume systems, and given the insulation properties of the hydride materials, it is beneficial to have an external heat transfer mechanism in addition to the storage material.

[0009] Another problem with hydride storage materials is that when the storage alloy absorbs hydrogen, it typically expands, causing the particles of the storage materials to grow and sometimes break apart. When hydrogen is released (usually due to heat), the storage material or hydrogenated material may shrink, possibly causing some particles to collapse. Continuous expansion and contraction of the storage medium causes the alloy or hydrogenated alloy particles to be broken down into progressively smaller particles. Although this process can increase the surface area of the alloy or stored material, there is a risk that very fine particles may filter the material and accumulate at the bottom of the container or become dense due to airflow, which is not ideal. Due to the compression and expansion of the hydrogen storage material during charging, densely packed areas of high density may cause significant stress on the container. Densification and expansion of hydrogen storage materials may cause containers holding the materials to deform, crack, or rupture. Therefore, designing a unique type of storage tank is sufficient to achieve efficient hydrogen storage performance.

[0010] Generally speaking, this type of hydrogen storage tank must have several features: a certain ability to withstand pressure, convenient hydrogen passage, a suitable interface contacted with the hydrogen storage alloy, and a design of the heating plate. A better previous example is the hydrogen storage device disclosed in **TW patent No. I304878**. The hydrogen storage device includes a reaction body, a hydrogen storage chamber, a hydrogen filter chamber, and a heat pipe unit. The hydrogen storage chamber is located inside the reaction body and is filled with hydrogen storage materials to absorb or release hydrogen. The hydrogen filter chamber is located in the reaction body and connected to the hydrogen storage chamber, and is used to confine the hydrogen storage material in the hydrogen storage chamber and allow hydrogen to enter and exit the hydrogen storage chamber. The heat pipe unit has a first heat exchange portion and a second heat exchange

portion connected and respectively located inside and outside the hydrogen storage chamber, so as to perform heat exchange with the hydrogen storage material through the first heat exchange portion. The heating plate of the second heat exchange part is heated to promote the hydrogen absorption or desorption reaction of the hydrogen storage material in the hydrogen storage chamber. Although the hydrogen storage device meets the above characteristics, since the heating plate liquid needs to transfer heat between the first heat exchange part and the second heat exchange part when heating the plate, it is necessary to repeatedly adjust the height position of both sides of the heating plate. It is difficult to operate. In addition to being inconvenient, the cooling effect is also poor.

[0011] In order to solve the problems of inconvenient operation and poor effect of the heating plate in the prior art and make the hydrogen storage operation safer and more effective, the present invention is proposed.

SUMMARY OF THE INVENTION

[0012] This paragraph extracts and compiles some features of the present invention; other features will be disclosed in the follow-up paragraphs. It is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims.

[0013] In order to solve the above problems and make hydrogen storage operations safer and more effective, a solid state hydrogen storage tank is provided. It includes: an outer shell, having a plurality of connecting openings opened on a side thereof; an inner shell, enclosed by the outer shell, wherein the inner shell and the outer shell are similar in appearance to a cylindrical shape; a plurality of heating plates, each heating plate being bent at a fixed angle and installed in the inner shell with portions of two adjacent heating plates parallelly arranged, so that an inner space of the inner shell is divided into several accommodation areas; a plurality of hydrogen pipes, guiding hydrogen into the inner shell for storage, and directing the hydrogen out of the inner shell when being used, wherein one end of each hydrogen pipe passes through and are closely connected with the outer shell and the inner shell, the other end is installed in a specific accommodation area, and a portion of the hydrogen pipe in the accommodation area has a plurality of hydrogen holes; a plurality of heat exchange coolant pipes, for cooling down a temperature inside the inner shell, wherein two ends of each heat exchange coolant pipe pass through and are closely connected to the outer shell and the inner shell, respectively, and a middle portion of each heat exchange coolant

pipe spirally surrounds one of the hydrogen pipes; a plurality of heating tubes, for heating up the temperature inside the inner shell, each heating tube being bent and extending between two adjacent heating plates; and magnesium-based hydrogen alloy powder, being placed in the accommodation areas to absorb and release hydrogen. The magnesium-based hydrogen alloy powder absorbs hydrogen from the hydrogen pipes after being heated by the heating plates. and can release the absorbed hydrogen to flow out through the hydrogen pipes after cooling down by a cooling fluid in the heat exchange coolant pipes and/or the cooling fluid passing through the connecting openings and flowing through a space between the outer shell and the inner shell when the heating plates stop heating and the hydrogen pipes stop supplying hydrogen.

[0014] According to the present invention, each heating plate has a plurality of protrusions formed toward a corresponding accommodation area to increase heating area to accelerate heat flow to the magnesium-based hydrogen alloy powder in the accommodation area.

[0015] According to the present invention, a filter is further set on a surface of the hydrogen pipe in the accommodation area to prevent the magnesium-based hydrogen alloy powder from entering the hydrogen pipe through the hydrogen holes.

[0016] Preferably, a grid width of the filter ranges from 5 microns to 500 microns.

[0017] Preferably, a pore size of the hydrogen holes ranges from 100 microns to 1000 microns.

[0018] Preferably, when heated, the temperature of each heating tube reaches between 300°C and 400°C.

[0019] According to the present invention , the fixed angle is $360^\circ/n$ and n is a positive integer not less than 2.

[0020] Preferably, the heating tubes are electric heating tubes with high resistance or heat conduction pipes with high thermal conductivity.

[0021] Preferably, a material of the magnesium-based hydrogen alloy powder is magnesium-nickel-hydrogen alloy, magnesium-aluminum-hydrogen alloy, magnesium-lanthanum-hydrogen alloy, magnesium-nickel-hydrogen alloy or magnesium-cobalt-hydrogen alloy.

[0022] Preferably, the outer shell and the inner shell are made of high-pressure stainless steel.

[0023] Preferably, the outer shell and the inner shell have a plurality of tube holes on the same end, and each tube hole of the outer shell and a corresponding tube hole of the inner shell are closely connected by a connecting tube, so as to fill the accommodating areas with the magnesium-based hydrogen alloy powder through the tube holes.

[0024] The present invention uses two different heat dissipation designs, which are easy to operate and can quickly achieve the expected heat dissipation effect, thus solving the above problems. Meanwhile, the design of the heating tube and the heating plate allows the magnesium-based hydrogen alloy powder to be heated faster and more evenly. In addition to making hydrogen storage operations safer and more efficient, it is also more convenient to take out the stored hydrogen.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Fig. 1 is a perspective view of a solid state hydrogen storage tank according to a first embodiment of the present invention.

[0026] Fig. 2 is a cross-sectional perspective view of the solid state hydrogen storage tank, wherein magnesium-based hydrogen alloy powder is taken out from the solid state hydrogen storage tank.

[0027] Fig. 3 is a side view of the combination of a heating plate, a hydrogen pipe, a heat exchange coolant pipe and a heating tube.

[0028] Fig. 4 is a three-dimensional view of the first hydrogen pipe and the first heat exchange coolant pipe during installation.

[0029] Fig. 5 shows the hydrogen pipe with a filter installed outside.

[0030] Fig. 6 is a three-dimensional view of the heating plate and heating tube during installation.

[0031] Fig. 7 is a side view of a combination of a heating plate, a hydrogen pipe, a heat exchange coolant pipe and a heating tube according to a second embodiment of the present invention.

[0032] Fig. 8 is a three-dimensional view of the first heat exchange coolant pipe.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0033] The present invention will be described more specifically with reference to the following embodiments.

[0034] See Fig. 1 and Fig. 2. Fig. 1 is a perspective view of a solid state hydrogen storage tank 1 according to a first embodiment of the present invention. Fig. 2 is a cross-sectional perspective view of the solid state hydrogen storage tank 1 (magnesium-based hydrogen alloy powder is taken out from the solid state hydrogen storage tank). The solid state hydrogen storage tank 1 includes an outer shell 10, an inner shell 20, a number of heating plates (in this embodiment, four heating plates are used as an example, namely, a first heating plate 31, a second heating plate 32, a third

heating plate 33 and a fourth heating plate 34), a number of hydrogen pipes (in this embodiment, four hydrogen pipes are used as an example, namely, a first hydrogen pipe 41, a second hydrogen pipe 42, a third hydrogen pipe 43 and a fourth hydrogen pipe 44), a number of heat exchange coolant pipes (in this embodiment, four heat exchange coolant pipes are used as an example, namely, a first heat exchange coolant pipe 51, a second heat exchange coolant pipe 52, a third heat exchange coolant pipe 53 and a fourth heat exchange coolant pipe 54), a number of heating tubes (in this embodiment, three heating tubes are used as examples, namely, a first heating tube 61, a second heating tube 62 and a third heating tube 63) and magnesium-based hydrogen alloy powder 70. The following introduces the types, functions and operation methods of these technical components.

[0035] As can be seen from Fig. 1, the outer shell 10 has a cylindrical appearance and has a number of connecting opening 11 opened on its side. The outer shell 10 is cylindrical in shape to match the outer shape of the inner shell 20. Its two ends are arc-shaped and gradually shrink. In practice, since the outer shell 10 is not subjected to hydrogen pressure, its appearance is not restricted by the outer shape of the inner shell 20. Function of the connecting opening 11 is to connect to an external cooling pipeline (not shown). An external cooling fluid is introduced through a cooling pipeline to cool down the heated inner shell 20, and the cooled fluid is discharged through another cooling pipeline. According to the present invention, the cooling fluid can be any cooling liquid or gas used to remove heat; for example, the former may be cooling water, liquid ammonia, propylene glycol or other liquid cooling compounds/mixtures, and the latter may be air, halogenated hydrocarbons or other gaseous cooling compounds/mixtures. In this embodiment, cooling water is used as an example. The connecting opening 11 is two in number and is located at the center of the outer shell 10. In practice, the number of the connecting opening 11 is not limited and may be any quantity above 2, for example, four connecting openings 11 that are equally spaced in the center. In addition, locations of the connecting openings 11 are not limited to being concentrated in the center, and may also be respectively arranged at both ends or concentrated at one end.

[0036] The inner shell 20 is enclosed by the outer shell 10. The inner space of the inner shell 20 is used to store hydrogen. Since hydrogen atoms bonded to the magnesium-based hydrogen alloy powder 70 are easily separated to form hydrogen molecules at room temperature, there is a huge pressure in the inner space of the inner shell 20. To ensure safe use, the inner shell 20 and the outer shell 10 are similar in appearance to a cylindrical shape. The two ends of the inner shell 20 are

preferably hemispherical. Such a design can avoid stress concentration at both ends of the inner shell 20 to reduce the maximum allowable pressure of the inner shell 20. Considering pressure resistance, it is best for both the outer shell 10 and the inner shell 20 to be made of high-pressure stainless steel. At least, the inner shell 20 needs to be made of high-pressure stainless steel. It can reduce rust while resisting pressure. In some designs, the inner diameter of the inner shell 20 can be 100-2500mm, the distance between the inner shell 20 and the outer shell 10 is 50-100 mm, and the total length of the outer shell 10 is 2500-5000 mm. The space between the inner shell 20 and the outer shell 10 can be used to inject cooling water (cooling fluid). The cooling water is circulated to take away the heat in the space and the inner shell 20, thus achieving a cooling effect. After being discharged, the used high-temperature cooling water can be cooled and reused.

[0037] In this embodiment, the number of the heating plates is 4. Each heating plate is bent at a fixed angle. All heating plates can be installed in the inner shell 20 with portions of two adjacent heating plates parallelly arranged, so that an inner space of the inner shell is equally divided into several accommodation areas A. Each heating plate has the same size and is formed by bending a metal plate (such as a copper plate) at the same fixed angle. See Fig. 3. It is a side view of a combination of a heating plate, a hydrogen pipe, a heat exchange coolant pipe and a heating tube. Take the first heating plate 31 as an example. Its bending fixed angle θ is 90 degrees. The right half of the first heating plate 31 is arranged in parallel with the left half of the third heating plate 33. The left half of the first heating plate 31 and the right half of the second heating plate 32 are arranged in parallel. The arrangement of other heating plates is the same. According to this principle, the inner shell is divided into four equal-sized accommodation areas A. Each accommodation area A can accommodate a hydrogen pipe, a heat exchange coolant pipe and a large amount of magnesium-based hydrogen alloy powder 70. The purpose of each heating plate is to heat the magnesium-based hydrogen alloy powder 70 in the accommodation area A. To improve the heating effect, each heating plate has a number of protrusions 30 formed toward the corresponding accommodation area to increase heating area, so as to accelerate heat flow to the magnesium-based hydrogen alloy powder 70 in the accommodation area A. The protrusion 30 can be formed by pressing the unformed heating plate surface with a die. Its top view shape is not limited to a circle; it can be any simple geometric shape.

[0038] According to the present invention, the number of the heating plate is not limited to 4 and can be any number above 2. It depends on the fixed angle θ . A limitation of the fixed angle θ is

$360^\circ/n$ and n is a positive integer not less than 2. When n is 2, the fixed angle θ is 180° (the heating plate does not need to be bent), the number of the heating plates is 2, and the inner space of the inner shell is divided into 2 equal-sized accommodation areas A.; when n is 3, the fixed angle θ is 120° , the number of the heating plates is 3, and the inner space of the inner shell is divided into 3 equal-sized accommodation areas A.; when n is 4, it is the present embodiment; when n is 5, the fixed angle θ is 72° , the number of the heating plates is 5, and the inner space of the inner shell is divided into 5 equal-sized accommodation areas A.; and so on.

[0039] The function of the hydrogen pipe is to guide hydrogen into the inner shell 20 for storage, and to direct hydrogen out of the inner shell 20 when being used. Each hydrogen pipe has the same structure. To illustrate its appearance, see Fig. 4. It is a three-dimensional view of the first hydrogen pipe 41 and the first heat exchange coolant pipe 51 during installation. Take the first hydrogen pipe 41 as an example. The first end 411 (closed end) of the first hydrogen pipe 41 and the main body are installed in one of the four accommodation areas A. A second end 412 of the first hydrogen pipe 41 passes through and are closely connected with the outer shell 10 and the inner shell 20. The first end 411 can be connected to an external hydrogen source, such as a hydrogen truck, through a pipeline to receive hydrogen to be stored, and release hydrogen through the original pipeline when hydrogen is needed. The first hydrogen pipe 41 is installed in a specific accommodation area A (the one formed by the first heating plate 31). See Fig. 5. It shows the hydrogen pipe with a filter installed outside. A portion of the first hydrogen pipe 41 in the accommodation area A has many hydrogen holes 413 (Fig. 5 shows three for illustration). The hydrogen hole 413 is the passage for hydrogen to enter and exit the first hydrogen pipe 41. The hydrogen hole 413 has a pore size d_1 and the pore size d_1 is limited. If the pore size d_1 is too large, although the amount of hydrogen entering and exiting is also large, the magnesium-based hydrogen alloy powder 70 may drift to the hydrogen hole 413 and flow to the outside along with the hydrogen. Hydrogen mixed with magnesium-based hydrogen alloy powder 70 may cause problems in using hydrogen equipment. If the pore size d_1 is too small, although the chance of the magnesium-based hydrogen alloy powder 70 flowing out of the inner shell 20 is greatly reduced, the amount of hydrogen entering and leaving is reduced, which prolongs the time to store hydrogen. In practice, preferably, a pore size of the hydrogen holes ranges from 100 microns to 1000 microns. Considering preventing the powdered magnesium-based hydrogen alloy powder 70 from flowing into the hydrogen hole, a filter N may be set on a surface of the hydrogen pipe 41 in the

accommodation area A. The filter N can be used to prevent the magnesium-based hydrogen alloy powder 70 from entering the hydrogen pipe 41 through the hydrogen holes 413. The material of the filter N is not limited. Preferably, it is a corrosion-resistant and wear-resistant metal mesh. The grid width d2 of the filter screen N is preferably slightly smaller than the pore size d1 of the hydrogen hole 413. In practice, the grid width d2 of the filter N may range from 5 microns to 500 microns.

[0040] The structures of the four heat exchange coolant pipes of the present invention are the same, and their design purpose is to cool down the temperature inside the inner shell 20. Take the first heat exchange coolant pipe 51 in Fig. 4 as an example. In Fig. 4, two ends of the first heat exchange coolant pipe 51 pass through and are closely connected to the outer shell 10 and the inner shell 20, respectively. A middle portion of the first heat exchange coolant pipe 51 spirally surrounds the first hydrogen pipe 41. Two ends of the first heat exchange coolant pipe 51 can be connected to a pump and a radiator (not shown), respectively, so that the cooling fluid can be cooled down quickly after leaving the solid state hydrogen storage tank 1. The cooled cooling fluid can be circulated back to the solid state hydrogen storage tank 1 for use.

[0041] See Fig. 6, it is a three-dimensional view of the heating plate and heating tube during installation. In Fig. 6, for the convenience of explanation, the first heating plate 31 and the third heating plate 33 are removed. The heating tube is for heating up the temperature inside the inner shell 20, to promote the combination of the magnesium-based hydrogen alloy powder 70 and hydrogen. Each heating tube is bent and extends between two adjacent heating plates. It can be seen from Fig. 6 that the first heating tube 61 is bent and extends between the first heating plate 31 and the third heating plate 33; the second heating tube 62 is bent and extends between the first heating plate 31 and the second heating plate 32, is also bent and extends between the third heating plate 33 and the fourth heating plate 34; the third heating tube 63 is bent and extends the second heating plate 32 and the fourth heating plate 34. Of course, The second heating tube 62 can also be split into two to heat the first heating plate 31 and the second heating plate 32, and the third heating plate 33 and the fourth heating plate 34, respectively. Considering the efficiency of heating, the heating tubes are preferably an electric heating tubes with high resistance. Its two ends are connected to the positive and negative poles of the power source to convert electricity into heat. In practice, the heating tubes may be heat conduction pipes with high thermal conductivity. According to the present invention, when heated, the temperature of each heating tube should at

least reach between 300°C and 400°C. During operation, the emission temperature can be stably maintained between 350°C and 380°C.

[0042] The magnesium-based hydrogen alloy powder 70 is placed in the accommodation areas A to absorb and release hydrogen. The material of magnesium-based hydrogen alloy powder 70 can be, but not limited to magnesium-nickel-hydrogen alloy, magnesium-aluminum-hydrogen alloy, magnesium-lanthanum-hydrogen alloy, magnesium-nickel-hydrogen alloy or magnesium-cobalt-hydrogen alloy.

[0043] When installing the solid state hydrogen storage tank 1 or when the solid state hydrogen storage tank 1 is in operation, it has to fill the inner shell 20 of the solid state hydrogen storage tank 1 with the magnesium-based hydrogen alloy powder. For this purpose, the solid state hydrogen storage tank 1 has a special design. See Fig. 1 again. The outer shell 10 and the inner shell 20 have a number of tube holes 12 with an inner diameter of about 30 mm correspondingly formed at the same end (The present invention does not limit the inner diameter of the tube hole 12) for filling the magnesium-based hydrogen alloy powder. In this embodiment, the outer shell 10 is illustrated by taking four tube holes 12 as an example, and the inner shell 20 also has four corresponding tube holes, which are blocked and cannot be seen in Fig. 1. The method is that each tube hole 12 is used to fill an accommodation area A with magnesium-based hydrogen alloy powder. However, in practice, it doesn't have to be a one-to-one correspondence. Each tube hole 12 of the outer shell 10 and a corresponding tube hole of the inner shell 20 are closely connected by a connecting tube (not shown), so as to fill the accommodating areas A with the magnesium-based hydrogen alloy powder through the tube holes. After the magnesium-based hydrogen alloy powder is added, the outside of the tube hole 12 can be closed with a cover plate (not shown).

[0044] The magnesium-based hydrogen alloy powder 70 absorbs hydrogen from the hydrogen pipe after being heated by the heating plates. The reaction is as described above and will not be repeated here. The magnesium-based hydrogen alloy powder 70 can be cooled down to release the absorbed hydrogen by a cooling fluid in the heat exchange coolant pipes and/or the cooling fluid passing through the connecting openings and flowing through a space between the outer shell 10 and the inner shell 20 when the heating plates stop heating and the hydrogen pipes stop supplying hydrogen. Meanwhile, the excess heat generated during the reaction is eliminated. The purpose of cooling is to stop the magnesium-based hydrogen alloy powder 70 from absorbing hydrogen and to allow the hydrogen to be stored at room temperature (closing the inlet and outlet of the hydrogen

pipe). Part of the high-temperature cooling fluid can also be directed to the outside to serve as another heat source to heat processes that require heat, thus reusing energy. In addition, after cooling down, the inlet and outlet of the hydrogen pipe are opened to release the absorbed hydrogen, which flows out through the hydrogen pipes and is supplied to the demand side.

[0045] In order to achieve a better heat dissipation effect, a second embodiment of the present invention proposes a different heat exchange coolant pipe design. See Fig. 7. It is a side view of a combination of a heating plate, a hydrogen pipe, a heat exchange coolant pipe and a heating tube according to the second embodiment of the present invention. Compared with the previous embodiment, in this embodiment, the first heat exchange coolant pipe 51, the second heat exchange coolant pipe 52, the third heat exchange coolant pipe 53 and the fourth heat exchange coolant pipe 54 are replaced by a first heat exchange coolant pipe 51', a second heat exchange coolant pipe 52', a third heat exchange coolant pipe 53' and a fourth heat exchange coolant pipe 54' in Fig. 7, respectively. The rest components remain unchanged. The first heat exchange coolant pipe 51', the second heat exchange coolant pipe 52', the third heat exchange coolant pipe 53' and the fourth heat exchange coolant pipe 54' have the same appearance design and function. Take the first heat exchange coolant pipe 51' as an example. See a three-dimensional view in Fig. 8. The first heat exchange coolant pipe 51' of this embodiment, when viewed from the extension direction, has a projection shape close to a quarter of a circle (including two perpendicular radii and a quarter of a circle arc). The first heat exchange coolant pipe 51' extends uniformly in the extension direction. This is different from the first heat exchange coolant pipe 51 of the previous embodiment, which is a round tube when viewed from the extension direction, and its appearance is similar to a commonly used spring. Since the first heat exchange coolant pipe 51' is closer to the first heating plate 31 and the inner shell 20 than the first heat exchange coolant pipe 51 of the previous embodiment, and the volume occupied in the accommodation area A is also larger, it has a better heat dissipation effect.

[0046] While the invention has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention needs not be limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims, which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

WHAT IS CLAIMED IS:

1. A solid state hydrogen storage tank, comprising:

an outer shell, having a plurality of connecting openings opened on a side thereof;

an inner shell, enclosed by the outer shell, wherein the inner shell and the outer shell are similar in appearance to a cylindrical shape;

a plurality of heating plates, each heating plate being bent at a fixed angle and installed in the inner shell with portions of two adjacent heating plates parallelly arranged, so that an inner space of the inner shell is divided into several accommodation areas;

a plurality of hydrogen pipes, guiding hydrogen into the inner shell for storage, and directing the hydrogen out of the inner shell when being used, wherein one end of each hydrogen pipe passes through and are closely connected with the outer shell and the inner shell, the other end is installed in a specific accommodation area, and a portion of the hydrogen pipe in the accommodation area has a plurality of hydrogen holes;

a plurality of heat exchange coolant pipes, for cooling down a temperature inside the inner shell, wherein two ends of each heat exchange coolant pipe pass through and are closely connected to the outer shell and the inner shell, respectively, and a middle portion of each heat exchange coolant pipe spirally surrounds one of the hydrogen pipes;

a plurality of heating tubes, for heating up the temperature inside the inner shell, each heating tube being bent and extending between two adjacent heating plates; and

magnesium-based hydrogen alloy powder, being placed in the accommodation areas to absorb and release hydrogen,

wherein the magnesium-based hydrogen alloy powder absorbs hydrogen from the hydrogen pipes after being heated by the heating plates, and can release the absorbed hydrogen to flow out through the hydrogen pipes after cooling down by a cooling fluid in the heat exchange coolant pipes and/or the cooling fluid passing through the connecting openings and flowing through a space between the outer shell and the inner shell when the heating plates stop heating and the hydrogen pipes stop supplying hydrogen.

2. The solid state hydrogen storage tank according to claim 1, wherein each heating plate has a plurality of protrusions formed toward a corresponding accommodation area to increase heating area to accelerate heat flow to the magnesium-based hydrogen alloy powder in the accommodation area.

3. The solid state hydrogen storage tank according to claim 1, wherein a filter is further set on a surface of the hydrogen pipe in the accommodation area to prevent the magnesium-based hydrogen alloy powder from entering the hydrogen pipe through the hydrogen holes.
4. The solid state hydrogen storage tank according to claim 3, wherein a grid width of the filter ranges from 5 microns to 500 microns.
5. The solid state hydrogen storage tank according to claim 1, wherein a pore size of the hydrogen holes ranges from 100 microns to 1000 microns.
6. The solid state hydrogen storage tank according to claim 1, wherein when heated, the temperature of each heating tube reaches between 300°C and 400°C.
7. The solid state hydrogen storage tank according to claim 1, wherein the fixed angle is $360^\circ/n$ and n is a positive integer not less than 2.
8. The solid state hydrogen storage tank according to claim 1, wherein the heating tubes are electric heating tubes with high resistance or heat conduction pipes with high thermal conductivity.
9. The solid state hydrogen storage tank according to claim 1, wherein a material of the magnesium-based hydrogen alloy powder is magnesium-nickel-hydrogen alloy, magnesium-aluminum-hydrogen alloy, magnesium-lanthanum-hydrogen alloy, magnesium-nickel-hydrogen alloy or magnesium-cobalt-hydrogen alloy.
10. The solid state hydrogen storage tank according to claim 1, wherein the outer shell and the inner shell are made of high-pressure stainless steel.
11. The solid state hydrogen storage tank according to claim 1, wherein the outer shell and the inner shell have a plurality of tube holes on the same end, and each tube hole of the outer shell and a corresponding tube hole of the inner shell are closely connected by a connecting tube, so as to fill the accommodating areas with the magnesium-based hydrogen alloy powder through the tube holes.