

CYCLIC METHOD AND EQUIPMENT FOR SOLID HYDROGEN-BASED HYDROGEN STORAGE AND TRANSPORTATION AT NORMAL TEMPERATURE AND PRESSURE

TECHNICAL FIELD

[0001] The present disclosure relates to the technical field of solid-hydrogen-based hydrogen storage and transportation at normal temperature and pressure, and in particular to a cyclic method and equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure.

BACKGROUND

[0002] At present, the commonly used hydrogen storage and transportation methods in China are as follows: high-pressure gaseous hydrogen storage, and low-temperature liquid hydrogen storage and transportation. The high-pressure gaseous hydrogen storage and transportation has been limited due to its safety development and is unsuitable for large-scale long-distance transportation due to its low hydrogen storage density. The low-temperature liquid hydrogen storage and transportation has high cost and difficulty in storage and transportation. The foregoing two methods not only have high cost, high pressure resistance requirements, low safety and low efficiency, but also have restrictions on transportation tools, routes and distances.

SUMMARY

[0003] An objective of the present disclosure is a cyclic method and equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure. Based on hydrogen storage characteristics of solid hydrogen, storage and transportation at normal temperature and pressure is achieved by cooperating with absorption-desorption cyclic equipment, with low risk and low cost, and the hydrogen storage characteristics can be repeatedly used to solve the technical problem of safe storage and transportation of hydrogen at normal pressure and temperature in the prior art.

[0004] To achieve the foregoing objective, the present disclosure provides the following technical solutions.

[0005] Cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure provided by the present disclosure includes a solid hydrogen cylinder, a hydrogen absorption module, and a hydrogen storage module.

[0006] The solid hydrogen cylinder is made of stainless steel, and a magnesium ingot is placed in

the solid hydrogen cylinder.

[0007] The hydrogen absorption module and the hydrogen storage module are both of modular design structures, and include intelligent heating equipment, where the intelligent heating equipment is configured to heat the solid hydrogen cylinder for hydrogen absorption or desorption. The hydrogen absorption module is configured to heat the solid hydrogen cylinder and continuously convey hydrogen into the solid hydrogen cylinder, so that the magnesium ingot can chemically react with the hydrogen to generate solid magnesium hydride. The hydrogen storage module is configured to heat the solid hydrogen cylinder containing the solid magnesium hydride to enable the solid magnesium hydride to release the hydrogen through a pyrolytic reaction and then store the hydrogen. The solid magnesium hydride, after the hydrogen is released, forms a magnesium ingot for reuse.

[0008] The intelligent heating equipment includes a human-machine interaction module, an intelligent control module, a power module, a heating module, a nano thermal insulation module, a temperature detection module, and a heat dissipation module.

[0009] The human-machine interaction module includes a visible digital model and a touch screen, the visible digital model is configured to display an operating condition of the intelligent heating equipment, and the touch screen is configured to control the intelligent heating equipment to adjust a heating temperature, a pressure and a heating sequence, thereby achieving speed control of hydrogen absorption and desorption.

[0010] The intelligent control module is electrically connected to the human-machine interaction module, the heating module, the temperature detection module and the heat dissipation module, and configured to achieve automatic control of the intelligent heating equipment.

[0011] The power module is electrically connected to the intelligent control module, the human-machine interaction module, the heating module, the temperature detection module and the heat dissipation module.

[0012] The heating module includes a mica high-temperature copper wire and a power supply wire. The mica high-temperature copper wire is wound outside the nano thermal insulation module, and the power supply wire is connected to the mica high-temperature copper wire. When the mica high-temperature copper wire is electrified to generate a magnetic field, the magnetic field generates an eddy current in the solid hydrogen cylinder to form self-heating.

[0013] The nano thermal insulation module includes a thermal insulation bracket made of a non-metallic thermal insulation material and a nano thermal insulation material made of a nano-microporous material. The solid hydrogen cylinder is placed in the thermal insulation bracket, and a non-metallic thermal insulation layer is formed by the thermal insulation bracket. A gap is left

between the solid hydrogen cylinder and an inner wall of the thermal insulation bracket to form a static air insulation layer; and the nano thermal insulation material is wound outside the thermal insulation bracket to form a nano thermal insulation layer.

[0014] The temperature detection module is mounted outside the nano thermal insulation module, and is in contact connection with the solid hydrogen cylinder in a spring probe manner to test a temperature of the solid hydrogen cylinder in real time.

[0015] The heat dissipation module is arranged in the thermal insulation bracket, and located at a lower portion of the solid hydrogen cylinder. The heat dissipation module includes air inlet holes formed in the thermal insulation bracket and a pressurized gas supply source connected to the air inlet hole. The air inlet holes are arranged around an entire circumference of the solid hydrogen cylinder, and an outlet axis of the air inlet hole is tangent to a pipe wall of the solid hydrogen cylinder.

[0016] Further, the heating module is arranged in a segmented structure along a vertical height direction, and each segment of the heating module is capable of being controlled independently controlled to accommodate solid-state hydrogen cylinders with different heights.

[0017] Further, the temperature detection modules are mounted at an upper portion, a middle portion and a lower portion of the nano thermal insulation module, respectively.

[0018] Further, the hydrogen absorption module includes a hydrogen storage tank, a gas pump, intelligent heating equipment, a tee valve, and a switch valve.

[0019] The hydrogen storage tank is connected to the gas pump through the switch valve to supply hydrogen;

[0020] the gas pump is connected to the solid hydrogen cylinder through the tee valve to vacuumize the cylinder; and

[0021] the intelligent heating equipment is in contact connection with the solid hydrogen cylinder for heating the solid hydrogen cylinder.

[0022] Further, the hydrogen storage module includes a hydrogen storage tank, a gas pump, intelligent heating equipment, a heat exchanger, a tee valve and a switch valve.

[0023] The hydrogen storage tank is connected to the gas pump through the switch valve;

[0024] the solid hydrogen cylinder is connected to the heat exchanger through the tee valve for hydrogen output;

[0025] the gas pump is connected to the heat exchanger and the tee valve; and

[0026] the intelligent heating equipment is in contact connection with the solid hydrogen cylinder for heating the solid hydrogen cylinder.

[0027] Further, the solid hydrogen cylinder includes a solid hydrogen cylinder body, an end cover,

a globe valve, a support bracket, and a magnesium ingot.

[0028] The solid hydrogen cylinder body is of a sealed tank structure with an open top;

[0029] the open top is covered with the end cover to form an integrally sealed solid hydrogen cylinder;

[0030] the globe valve is mounted at an inlet/outlet of the end cover;

[0031] the support bracket is mounted in the solid hydrogen cylinder body; and

[0032] the magnesium ingot is placed on the support bracket.

[0033] Further, the solid hydrogen cylinder further includes a bottom anti-collision sleeve and a valve body protection sleeve.

[0034] The bottom anti-collision sleeve is sleeved at the bottom of the solid hydrogen cylinder body; and

[0035] the valve body protection sleeve is sleeved outside the globe valve.

[0036] Further, the solid hydrogen cylinder further includes a sealing washer, a mounting bolt, an eyebolt, a safety valve, and a deflation valve.

[0037] The sealing washer is arranged at a joint of the end cover and the solid hydrogen cylinder body;

[0038] the mounting bolt and the eyebolt are used to connect the end cover and the solid hydrogen cylinder body; and

[0039] the safety valve and the deflation valve are arranged on a gas pipe connected to the globe valve in turn.

[0040] Further, the support bracket includes a support pipeline and a support plate. The support pipeline is vertically arranged in the solid hydrogen cylinder body, multiple support plates are uniformly arranged in an axial direction of the support pipeline; and the magnesium ingot is arranged on the support pipeline in a penetrating manner, and attached to each layer of support plate.

[0041] Further, the cyclic equipment further includes transportation equipment, which is configured to reciprocally transport the solid hydrogen cylinder between the hydrogen absorption module and the hydrogen storage module.

[0042] The present disclosure provides a cyclic method for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure, where the foregoing equipment is used for performing the cyclic method, and the method includes the following steps:

[0043] step S1, hoisting a solid hydrogen cylinder into intelligent heating equipment in a hydrogen absorption module;

[0044] step S2, vacuumizing the solid hydrogen cylinder;

[0045] step S3, supplying hydrogen into the solid hydrogen cylinder, and supplying power to a mica high-temperature copper wire at the same time to generate a magnetic field, where the magnetic field generates an eddy current in the solid hydrogen cylinder made of stainless steel after passing through a nano thermal insulation module; enabling the stainless-steel solid hydrogen cylinder to start self-heating under an own resistance condition, making a magnesium ingot placed in the solid hydrogen cylinder react with hydrogen to generate solid magnesium hydride to complete a hydrogen absorption process, specifically, introducing the hydrogen into the solid hydrogen cylinder, transmitting, by a pressure sensor, a signal to the intelligent heating equipment when a pressure reaches 1 MPa, where the intelligent heating equipment turns on an appropriate number of heating module segments according to a height of the solid hydrogen cylinder, where and the magnesium ingot reacts with the hydrogen at 380-480°C to generate magnesium hydride; after the hydrogen absorption is completed, discharging residual hydrogen by a gas pump, removing a hydrogen conveying pipe, closing a globe valve, and taking out, by hoisting equipment, the solid hydrogen cylinder containing the solid magnesium hydride through a lifting ring;

[0046] step S4, transporting the solid hydrogen cylinder that completes hydrogen absorption to a required position;

[0047] step S5, hoisting the solid hydrogen cylinder after hydrogen absorption into a hydrogen storage module; and

[0048] step S6, vacuumizing a heat exchanger in the hydrogen storage module and a hydrogen outlet pipeline, then heating the solid hydrogen cylinder after hydrogen absorption to release the hydrogen from the solid magnesium hydride, storing the released hydrogen by the hydrogen storage module to complete a hydrogen desorption process, specifically, turning on, by intelligent heating equipment in the hydrogen storage module, different segments of heating modules according to a height of the solid hydrogen cylinder, with a heating temperature of 400-550°C, and releasing the hydrogen; conveying, by the gas pump, the hydrogen to the heat exchanger for cooling, and then conveying the hydrogen to a hydrogen storage tank, where the hydrogen storage tank outputs the hydrogen to the outside to complete the hydrogen desorption process; and after the hydrogen is discharged, disconnecting a gas pipe, closing the globe valve, taking out, by hoisting equipment, the solid hydrogen cylinder containing solid magnesium through a lifting ring; and repeating steps S1-S6 to achieve cyclic hydrogen transportation at normal temperature and pressure.

[0049] In steps S3 and S6, in the process of heating the solid hydrogen cylinder by the intelligent heating equipment, when the intelligent control module sends out an emergency heat dissipation

command, a pressurized gas supply source in a heat dissipation module is started, a pressurized heat dissipation gas enters through an air inlet hole located on a thermal insulation bracket and is blown tangentially towards an entire circumference of a lower sidewall of the solid hydrogen cylinder, and the injected pressurized heat radiation gas rises around a circumferential direction of the solid hydrogen cylinder and is ultimately discharged from the top of the solid hydrogen cylinder.

[0050] It should be noted here that to achieve a helical rising airflow better, the outlet axis of the air inlet hole can form a certain angle with a horizontal plane, the air inlet hole is angled upwards, so that the air blown out through the air inlet hole is in an upwardly inclined airflow direction. Certainly, the outlet axis of the air inlet hole may be parallel to the horizontal plane.

[0051] According to the present disclosure, after a magnesium ingot in a solid hydrogen cylinder is heated by heating equipment in a hydrogen absorption place and hydrogen is introduced into the solid hydrogen cylinder, the magnesium ingot reacts with the hydrogen to obtain solid magnesium hydride, thereby completing a hydrogen absorption process. The solid hydrogen cylinder at normal temperature and pressure is transported to a hydrogen release place, and then the hydrogen is released by the heating equipment. At this time, the solid magnesium hydride is transformed into the magnesium ingot. The solid hydrogen cylinder stored with the magnesium ingot is returned to a hydrogen absorption place for continuous hydrogen absorption. In this way, the purpose of cyclic hydrogen transportation is implemented through the circulation of the solid hydrogen cylinder.

[0052] The present disclosure provides a cyclic method and equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure. Based on optimal design of solid magnesium hydride in each link of hydrogen absorption, hydrogen desorption, hydrogen storage and hydrogen transportation, hydrogen storage and transportation at normal temperature and pressure is achieved with safety and reliability, and the cost of each link is greatly reduced. Hydrogen transportation at normal temperature and pressure can be completed for many times by filling the magnesium ingot at one time, which greatly improves the safety and reduces the cost, and is beneficial to the industrialization and large-scale transportation of solid hydrogen storage. The present disclosure overcomes the constraints of transportation distance and end-user deployment scale for hydrogen, thereby pioneering a new pathway for popularizing the utilization of hydrogen energy. An intelligent heating module employed by the present disclosure can be configured to heat the solid hydrogen cylinder by using an electromagnetic effect heating method during heating, and a gap is formed between the solid hydrogen cylinder and the thermal insulation bracket. The gap forms a static air insulation layer to reduce outward dissipation of heat from the solid hydrogen cylinder during heating and achieve thermal insulation effect on the solid hydrogen cylinder and a space. In addition, due to good thermal insulation effect, the heating efficiency is

increased, the solid hydrogen cylinder and a gap space can be rapidly heated. As the heat dissipation module is arranged in the space, the heating module and the heat dissipation module are separately arranged, and the heat dissipation module is arranged at a lower portion of the solid hydrogen cylinder. The air inlet hole is formed in an inclined manner, so that the air can be blown out in an upward inclined manner. Pressurized cold air can be blown into the gap space from an air inlet hole at the lower portion in case of emergency to blow air onto the surface of the solid hydrogen cylinder, and then the cold air quickly rises to be discharged to implement rapid heat dissipation and cooling of the solid hydrogen cylinder and the gap space, so that production efficiency is improved, and production safety is ensured.

[0053] The present disclosure also has the advantages that the whole system is simple in structure, safe, environment-friendly, and simple and easy to control. Hydrogen storage at normal temperature and pressure can be achieved. The solid hydrogen cylinder enables cyclic reuse, supports mass production, can achieve long-distance hydrogen transportation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0054] To describe technical solutions of embodiments of the present disclosure or in the prior art more clearly, the following briefly introduces the accompanying drawings required for describing the embodiments or the prior art. Apparently, the accompanying drawings in the following description show merely some embodiments of the present disclosure, and those of ordinary skill in the art may still derive other drawings from these accompanying drawings without creative efforts.

[0055] FIG. 1 is a diagram of a structure of a hydrogen storage module in cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to the present disclosure;

[0056] FIG. 2 is a sectional diagram of a solid hydrogen cylinder in cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to the present disclosure;

[0057] FIG. 3 is a diagram of an orientation of air blown out from an air inlet hole in cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to the present disclosure;

[0058] FIG. 4 is a top cross-sectional view showing the internal of a thermal insulation bracket in which a solid hydrogen cylinder in cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to the present disclosure is placed;

[0059] FIG. 5 is a diagram of a partial structure of a solid hydrogen cylinder in cyclic equipment

for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to the present disclosure;

[0060] FIG. 6 is a partial axonometric diagram of a horizontal section of a thermal insulation bracket when a solid hydrogen cylinder in cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to the present disclosure is placed in the thermal insulation bracket;

[0061] FIG. 7 is a partial axonometric diagram of a vertical section of a thermal insulation bracket when a solid hydrogen cylinder in cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to the present disclosure is placed in the thermal insulation bracket.

[0062] In the drawings: 1-intelligent heating equipment; 2-solid hydrogen cylinder; 3-heat exchanger; 4-gas pump; 5-hydrogen storage tank; 6-tee valve; 7-first globe valve; 11-human-machine interaction module; 12-intelligent control module; 13-power module; 14-heating module; 15-nano thermal insulation module; 16-heat dissipation module; 17-temperature detection module; 21-globe valve; 22-end cover; 23-solid hydrogen cylinder body; 24-bottom anti-collision sleeve; 25-valve body protection sleeve; 26-bolt; 27-eyebolt; 28-magnesium ingot; 29-support bracket; 30-air duct; 31-air inlet hole.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0063] To make the objectives, technical solutions and advantages of the present disclosure more clearly, the following describes the technical solutions in the embodiments of the present disclosure in detail. Apparently, the described embodiments are merely a part rather than all of the embodiments of the present disclosure. All other implementations obtained by those of ordinary skill in the art based on the embodiments of the present disclosure without creative efforts shall fall within the scope of protection of the present disclosure.

[0064] The present disclosure provides cyclic equipment for solid hydrogen-based hydrogen storage and transportation. Based on hydrogen storage characteristics of solid hydrogen, the cyclic equipment can achieve hydrogen storage and transportation at normal temperature and pressure by cooperating with absorption-desorption cyclic equipment, with low risk and low cost, and the solid hydrogen can be repeatedly used to solve the technical problem of storage and transportation of hydrogen at normal pressure and temperature in the prior art. Absorption-desorption process of the hydrogen can be completed through terminal equipment, a closed-loop process of hydrogen absorption, hydrogen storage, hydrogen transportation and hydrogen desorption is achieved, where the solid hydrogen storage cylinder can be reused, which greatly reduces the cost of hydrogen

storage, hydrogen transportation and hydrogen use.

[0065] Specifically, the cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure provided by the present disclosure includes a solid hydrogen cylinder 2, a hydrogen absorption module, and a hydrogen storage module.

[0066] The solid hydrogen cylinder 2 is made of stainless steel, and a magnesium ingot 28 is placed in the solid hydrogen cylinder.

[0067] The hydrogen absorption module and the hydrogen storage module are both of modular design structures, and include intelligent heating equipment 1, and the intelligent heating equipment can be configured to heat the solid hydrogen cylinder 2 for hydrogen absorption or desorption. Specifically, in this embodiment:

[0068] the intelligent heating equipment 1 includes a human-machine interaction module 11, an intelligent control module 12, a power module 13, a heating module 14, a nano thermal insulation module 15, a temperature detection module 17, and a heat dissipation module 16.

[0069] The human-machine interaction module 11 includes a visible digital model and a touch screen, the visible digital model is configured to display an operating condition of the intelligent heating equipment, and the touch screen is configured to control the intelligent heating equipment to adjust operating parameters of the equipment, such as a heating temperature, a pressure, and a heating sequence, thereby achieving speed control of hydrogen absorption and desorption, and meeting demands of a customer.

[0070] The intelligent control module 12 is a control center of the intelligent heating equipment, and is electrically connected to the human-machine interaction module 11, the heating module 14, the temperature detection module 17 and the heat dissipation module 16, and configured to achieve automatic control of the intelligent heating equipment 1 and adaptively maintain a heating temperature. When the decrease of an external ambient temperature leads to excessive loss of the heating heat, the heating temperature can be compensated in time. When a reaction in the solid hydrogen cylinder 2 releases a lot of heat violently, an in-furnace temperature can be reduced at a uniform speed through the heat dissipation module 16 to ensure that the in-furnace temperature is within a suitable range. In addition, a hydrogen pressure, the progress of hydrogen absorption and desorption, emergency hydrogen release, emergency cooling and other commands are monitored.

[0071] The power module 13 is electrically connected to the intelligent control module 12, the human-machine interaction module 11, the heating module 14, the temperature detection module 17 and the heat dissipation module 16. Specifically, the power module 13 can provide stable voltage and current for the intelligent heating equipment through multiple capacitors, thereby ensuring stable heating.

[0072] The heating module 14 is a module for converting electric energy into heat energy, which includes a mica high-temperature copper wire and a power supply wire. The mica high-temperature copper wire is wound outside the nano thermal insulation module 15, and the power supply wire is connected to the mica high-temperature copper wire. When the mica high-temperature copper wire is electrified to generate a magnetic field, the magnetic field passes through the nano thermal insulation module 15 to generate an eddy current in the solid hydrogen cylinder 2 made of stainless steel. The stainless-steel solid hydrogen cylinder 2 starts to heat itself due to resistance, that is, the magnetic field generates the eddy current in the solid hydrogen cylinder 2 to form self-heating. In this case, the stainless-steel solid hydrogen cylinder 2 serves as a heating furnace to heat the magnesium ingot or solid magnesium hydride in the cylinder to achieve the objective of hydrogen absorption and desorption.

[0073] To improve an applicable range of the equipment, as an alternative implementation of the present disclosure, the heating module 14 is arranged in a segmented structure along a vertical height direction, and each segment of the heating module 14 can be independently controlled to accommodate solid hydrogen cylinders 2 with different heights. That is, the wound mica high-temperature copper wire can be arranged in segments and in multiple layers to meet the requirements of solid hydrogen cylinders with different heights or diameters.

[0074] In this embodiment, the mica high-temperature has a copper core stranded by multiple oxygen-free copper wires, a fluorophlogopite layer as a middle layer, and an alkali-free glass fiber woven layer outside, which meets the requirements of high-temperature flame retardant.

[0075] The nano thermal insulation module 15 is of a structure with three thermal insulation layers, including a thermal insulation bracket made of a non-metallic thermal insulation material, and a nano thermal insulation material made of a nano microporous material. The solid hydrogen cylinder 2 is placed in the thermal insulation bracket, and the thermal insulation bracket is made of a non-metallic material. The thermal insulation bracket forms a nonmetallic thermal insulation layer, which directly blocks heat conduction, heat convection and heat radiation of a heat source (the solid hydrogen cylinder 2). There is a gap between the solid hydrogen cylinder 2 and an inner wall of the thermal insulation bracket to form a static air insulation layer. The nano thermal insulation material is wound outside the thermal insulation bracket, with a thickness of 10 mm to 30 mm to form a nano thermal insulation layer. The nano thermal insulation module 15 effectively blocks heat transfer and concentrates the heat in the solid hydrogen cylinder, thereby saving energy consumption.

[0076] It should be noted here that the nano thermal insulation material in this embodiment is a nano microporous material. Spherical polymer particles with a size of about 2 to 5 nanometers are

combined with each other into small units, and then combined into a dendritic micro-stereoscopic structure. These small units form a fractal chain-like three-dimensional structure which is filled with a large number of pores, where each of the pores is no more than 100 nanometers in size. These pores can retain air, thereby blocking heat conduction, heat convection and heat radiation, and playing a role of thermal insulation and reducing heat loss.

[0077] The temperature detection module 17 is configured to provide temperature detection data to the intelligent control module 12, which is mounted outside the nano thermal insulation module 15 and in contact connection with the solid hydrogen cylinder 2 in a spring probe manner to test a temperature of the solid hydrogen cylinder 2 in real time. To improve measurement accuracy, in this embodiment, the temperature detection modules 17 are mounted at an upper portion, a middle portion and a lower portion of the nano thermal insulation module 15 to correspond to different heights of the solid hydrogen cylinder 2. In an optimal embodiment, a height of the solid hydrogen cylinder 2 is divided into three parts, namely, upper, middle and lower parts, and the temperature detection modules 17 are respectively mounted at the upper, middle and lower parts to increase the data collection reference and prevent control failure caused by failure of a single probe.

[0078] As shown in FIG. 2 to FIG. 7, the heat dissipation module 16 is an efficient ventilation system for executing an emergency heat dissipation command from the intelligent control command. Specifically, the heat dissipation module 16 is arranged in the thermal insulation bracket and located at a lower portion of the solid hydrogen cylinder 2. The heat dissipation module 16 includes air inlet holes 31 formed in the thermal insulation bracket, and a pressurized gas supply source connected to the air inlet hole 31. The air inlet holes 31 are arranged around an entire circumference of the solid hydrogen cylinder 2, and an outlet axis of the air inlet hole 31 is tangent to a pipe wall of the solid hydrogen cylinder 2, more preferably, it is inclinedly tangent. The inclination here means that there is an included angle between the outlet axis of the air inlet hole 31 and a horizontal plane, which is an upward inclination. When a high temperature occurs, high-pressure cold air is injected into a gap between the thermal insulation bracket and the heat source (solid hydrogen cylinder 2) through the air inlet hole 31, and the injected cold air is helically discharged around the heat source (the solid hydrogen cylinder) to discharge excessive heat, thereby achieving the objective of emergency heat dissipation.

[0079] It should be noted here that the pressurized gas supply source may include an air compressor, or an air blower, which communicates with the air inlet hole 31 through a pipeline. Certainly, as there are multiple air inlet holes 31 arranged along the entire circumference, an outer wall of the thermal insulation bracket can be provided with an air duct 30 along the entire circumference, and the pipeline communicates with the air duct 30. The air duct 30 communicates

with each air inlet hole 31, and the pipeline is connected to the air compressor or the air blower. The high-pressure cold air enters the air duct 30 through the pipeline, then is blown into a space gap between the thermal insulation bracket and the solid hydrogen cylinder 2 via each air inlet hole 31, and is finally blown to the surface of the entire circumference of the solid hydrogen cylinder 2. As the air inlet holes 31 are located at a peripheral side of the lower portion of the solid hydrogen cylinder 2, although the blown cold air is the pressurized cold air, it can only be directly blown to the lower position of the solid hydrogen cylinder 2. To discharge the heat rapidly, the air inlet hole 32 is configured as an inclined structure, that is, there is an included angle between the outlet axis of the air inlet hole 31 and the horizontal plane, the air outlet hole is an upward inclined structure, and an extension line of the central axis of the air inlet hole 31 is tangent to an outer wall of the solid hydrogen cylinder 2. Therefore, the blown pressurized cold air can form a helical airflow to flow upward when blown onto the surface of the solid hydrogen cylinder 2, thereby making contact with surfaces of the middle portion and the upper portion by means of the helical airflow to take away heat in the helical rising process to achieve rapid cooling and heat dissipation. **[0080]** FIG. 3 is a diagram showing that an air outlet axis of the air inlet hole 31 is tangent to an outer wall of the solid hydrogen cylinder from a top view direction.

[0081] An intelligent heating module employed by the present disclosure can be configured to heat the solid hydrogen cylinder by using an electromagnetic effect heating method during heating, and a gap is formed between the solid hydrogen cylinder and the thermal insulation bracket. The gap forms a static air insulation layer to reduce outward dissipation of heat from the solid hydrogen cylinder during heating and achieve thermal insulation effect on the solid hydrogen cylinder and a space. In addition, due to good thermal insulation effect, the heating efficiency is increased, the solid hydrogen cylinder and a gap space can be rapidly heated. As the heat dissipation module is arranged in the space, the heating module and the heat dissipation module are separately arranged, and the heat dissipation module is arranged at a lower portion of the solid hydrogen cylinder. The air inlet hole 31 is formed in an inclined manner, so that the air can be blown out in an upward inclined manner. Pressurized cold air can be blown into the gap space from an air inlet hole at the lower portion in case of emergency to blow air onto the surface of the solid hydrogen cylinder, and then the cold air quickly rises to be discharged to implement rapid heat dissipation and cooling of the solid hydrogen cylinder and the gap space, so that production efficiency is improved, and production safety is ensured. The device provided by the present disclosure can be arranged in a modular manner, which is suitable for mass production and manufacturing and can improve production efficiency.

[0082] The hydrogen absorption module is configured to heat the solid hydrogen cylinder 2 and

continuously convey hydrogen inward to make the magnesium ingot 28 react with the hydrogen to generate solid magnesium hydride.

[0083] The transportation equipment is configured to transport the solid hydrogen cylinder 2. Because the solid magnesium hydride can be transported by common transportation equipment, transportation cost and transportation control can be improved, transportation safety is improved, and hydrogen transportation at normal pressure and temperature can be achieved.

[0084] The hydrogen storage module is configured to heat the solid hydrogen cylinder 2 containing the solid magnesium hydride to enable the solid magnesium hydride to release the hydrogen through a pyrolytic reaction and then store the hydrogen, where the solid magnesium hydride, after the hydrogen is released, forms a magnesium ingot 28 for reuse.

[0085] Principle formulas involved in the process of hydrogen absorption and hydrogen desorption of the present disclosure is as follows:

[0086] $\text{Mg} + \text{H}_2 \rightarrow \text{MgH}_2$;

[0087] $\text{MgH}_2 \rightarrow \text{Mg} + \text{H}_2$.

[0088] The present disclosure also has the advantages that the whole system is simple in structure, safe, environment-friendly, and simple and easy to control. Hydrogen storage at normal temperature and pressure can be achieved. The solid hydrogen cylinder 2 enables cyclic reuse, is easier to achieve industrialized and scalable hydrogen logistics, supports mass production, can achieve long-distance hydrogen transportation, and adapts to diverse hydrogen use scenario.

[0089] Moreover, the cyclic equipment provided by the present disclosure can be expanded according to the hydrogen demand of customers. For example, multiple solid hydrogen cylinders 2 can be used for hydrogen output at the same time, thereby providing large-flow hydrogen. The solid hydrogen cylinder 2 at normal temperature and pressure can be transported by existing transportation equipment for gas cylinders (oxygen cylinders) without updating the existing equipment and fixtures, which greatly saves the transportation cost. The solid hydrogen cylinder 2 at normal temperature and pressure provided by the present disclosure is a sealed container, and when the container is filled with solid magnesium or solid magnesium hydride, it can be transported according to a normal logistics transportation system.

[0090] Further, the hydrogen absorption module includes a hydrogen storage tank 5, a gas pump 4, intelligent heating equipment 1, a tee valve 6, and a switch valve (not shown in the accompanying drawing).

[0091] The hydrogen storage tank 5 is connected to the gas pump 4 through the switch valve to supply hydrogen. It should be noted here that a third port of the tee valve 6 is in a normally closed state.

[0092] The gas pump 4 is connected to the solid hydrogen cylinder 2 through the tee valve 6 to vacuumize the cylinder.

[0093] The intelligent heating equipment 1 is in contact connection with the solid hydrogen cylinder 2 for heating the solid hydrogen cylinder 2.

[0094] Further, as shown in FIG. 1, the hydrogen storage module includes a hydrogen storage tank 5, a gas pump 4, intelligent heating equipment 1, a heat exchanger 3, a tee valve 6, and a switch valve (not shown in the accompanying drawings).

[0095] The switch valve of the hydrogen storage tank 5 is connected to the gas pump 4 to receive cooled hydrogen. Specifically, the heat exchanger 3 is a stainless-steel heat sink, which is configured to keep the hydrogen at a normal temperature state during hydrogen absorption or desorption. The hydrogen storage tank 5 is a storage container of hydrogen during hydrogen absorption and desorption.

[0096] The solid hydrogen cylinder 2 is connected to the heat exchanger 3 through the tee valve 6 for hydrogen output.

[0097] The gas pump 4 is connected to the gas pump 4 and the tee valve 6 for controlling a pressure of the hydrogen.

[0098] The intelligent heating equipment 1 is in contact connection with the solid hydrogen cylinder 2 for heating the solid hydrogen cylinder 2.

[0099] Further, as shown in FIG. 2, the solid hydrogen cylinder 2 includes a solid hydrogen cylinder body 23, an end cover 22, a globe valve 21, a support bracket 29, and a magnesium ingot 28.

[00100] The solid hydrogen cylinder body 23 is a sealed tank structure with an open top.

[00101] The open top is covered with the end cover 22 to form an integrally sealed solid hydrogen cylinder 2.

[00102] The globe valve 21 is mounted at an inlet/outlet of the end cover 22.

[00103] The support bracket 29 is mounted in the solid hydrogen cylinder body 23.

[00104] The magnesium ingot 28 is placed on the support bracket 29.

[00105] It should be noted here that after the solid hydrogen cylinder 2 completes hydrogen absorption, the solid magnesium hydride is placed on the support bracket 29.

[00106] Further, the solid hydrogen cylinder 2 further includes a bottom anti-collision sleeve 24, and a valve body protection sleeve 25.

[00107] The bottom anti-collision sleeve 24 is sleeved at the bottom of the solid hydrogen cylinder body 23.

[00108] The valve body protection sleeve 25 is sleeved outside the globe valve 21.

[00109] Further, the solid hydrogen cylinder 2 further includes a sealing washer, a mounting bolt 26, an eyebolt 27, a safety valve, and a deflation valve.

[00110] The sealing washer is arranged at a joint of the end cover 22 and the solid hydrogen cylinder body 23.

[00111] The mounting bolt 26 and the eyebolt 27 are used to connect the end cover 22 and the solid hydrogen cylinder body 23. The number of the eyebolts 27 is four, which are spaced apart, that is, the end cover 22 and the solid hydrogen cylinder body 23 are connected by the bolt 26 and the eyebolts 27.

[00112] The safety valve and the deflation valve are arranged on a gas pipe connected to the globe valve 21 in turn.

[00113] Further, the support bracket 29 includes a support pipeline and a support plate. The support pipeline is vertically arranged in the solid hydrogen cylinder body 23. The multiple support plates are uniformly arranged in an axial direction of the support pipeline. The magnesium ingot 28 is arranged on the support pipeline in a penetrating manner, and attached to each layer of support plate.

[00114] It should be noted here that in this embodiment, the solid hydrogen cylinder 2 includes the solid hydrogen cylinder body 23, the end cover 22, the globe valve 21, the safety valve, the deflation valve, the valve body protection sleeve 25, the sealing washer, the bolt 26, the eyebolt 27, the support bracket 29, the bottom anti-collision sleeve 24, and the solid magnesium hydride or magnesium ingot 28.

[00115] The solid hydrogen cylinder body 23 is a sealing member, one end of which is an open port and is connected to the end cover 22 by a flange, and the other end is externally provided with the bottom anti-collision sleeve 24. The end cover 22 is a flange port, and provided with valve parts at the top. A hollow-out protective cover, namely, the valve body protection sleeve 25, is designed at the outer side of the valve parts. The sealing washer is used between the solid hydrogen cylinder body 23 and the end cover 22, and the solid hydrogen cylinder body 23 and the end cover 22 are mechanically connected by, but not limited to, the bolt 26. The support bracket 29 is designed inside the solid hydrogen cylinder body 23, which is composed of the support pipeline and the support plate, where the support pipeline runs through the whole solid hydrogen cylinder body 23, and the support plate is not limited to a circular plate structure. The support plate is connected to the support pipeline, and the magnesium ingot 28 or solid magnesium hydride is placed on the support plate.

[00116] The present disclosure relates to the application of solid magnesium hydride which is a solid hydrogen storage material. The solid magnesium hydride is a solid metal magnesium ingot

in a state of not absorbing hydrogen, and the magnesium ingot is made into a cylindrical honeycomb shape, and the honeycomb metal magnesium ingots are superposed by the support bracket 29 with a proper gap between the magnesium ingots, and then the magnesium ingots are filled into the solid hydrogen cylinder 2 and encapsulated. The solid hydrogen cylinder 2 is a peripherally sealed container, which is designed with the globe valve 21 (on the cylinder body), the safety valve and the deflation valve at an end portion, and designed with a lifting ring structure for hoisting at the top.

[00117] The hydrogen absorption module and the hydrogen storage module in the present disclosure both include intelligent heating equipment 1, while the intelligent heating equipment is designed as a stationary structure, requiring only the hoisting of the solid hydrogen cylinder for loading and unloading. The intelligent heating equipment includes a human-machine interaction module 11, an intelligent control module 12, a power module 13, a heating module 14, a nano thermal insulation module 15, a temperature detection module 17, and a heat dissipation module 16. The human-machine interaction module 11 is configured to display an operating condition of the equipment through a visible digital model, and an operation on the equipment is achieved through a touch-screen function. The intelligent control module 12 is a control core of the intelligent heating equipment, which is configured to control a heating temperature, heating time, a hydrogen pressure, the progress of hydrogen absorption and desorption, emergency hydrogen release, emergency cooling, and other commands. The power module 13 is configured to provide stable voltage and current for the intelligent heating equipment. The heating module 14 is a module for converting electric energy into heat energy. The nano thermal insulation module 15 effectively blocks the heat transfer, and concentrates the heat into the solid hydrogen cylinder 2, thereby saving energy consumption. The temperature detection module 17 is configured to provide temperature detection data for the intelligent control module 12. The heat dissipation module 16 is an efficient ventilation system for executing an emergency heat dissipation command from the intelligent control module 12. In addition, a heat exchanger is arranged at the hydrogen storage module, and the heat exchange is configured to maintain the hydrogen at a normal temperature state when used for hydrogen absorption and desorption.

[00118] Further, the cyclic equipment further includes transportation equipment, which is configured to reciprocally transport the solid hydrogen cylinder between the hydrogen absorption module and the hydrogen storage module.

[00119] The present disclosure provides a cyclic method for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure, where the foregoing equipment is used for carrying out the cyclic method, and the method includes the following steps.

[00120]Step S1: A solid hydrogen cylinder 2 is hoisted into intelligent heating equipment in a hydrogen absorption module, specifically, hoisting equipment places the solid hydrogen cylinder 2 into a thermal insulation bracket of the intelligent heating equipment 1 through a lifting ring.

[00121]Step S2: The solid hydrogen cylinder is vacuumized. Specifically, a gas pipe fitting is connected, a globe valve 21 of the solid gas cylinder is opened, the air in the cylinder is discharged through an exhaust port of a gas pump 4, making vacuum degree reach 80 KPa and more, then the exhaust port of the gas pump 4 is closed, and the gas pump 4 is reversely operated for hydrogen conveying.

[00122]Step S3: Hydrogen is supplied into the solid hydrogen cylinder 2, and power is supplied to a mica high-temperature copper wire at the same time to generate a magnetic field, where the magnetic field generates an eddy current in the solid hydrogen cylinder made of stainless steel after passing through a nano thermal insulation module; the stainless-steel solid hydrogen cylinder starts self-heating under its own resistance condition, making a magnesium ingot placed in the solid hydrogen cylinder react with hydrogen to generate solid magnesium hydride to complete a hydrogen absorption process. Specifically, the hydrogen is introduced into the solid hydrogen cylinder, a pressure sensor transmits a signal to the intelligent heating equipment when a pressure reaches 1 MPa, where the intelligent heating equipment turns on an appropriate number of heating module segments according to a height of the solid hydrogen cylinder, where and the magnesium ingot reacts with the hydrogen at 380-480°C to generate magnesium hydrate; after the hydrogen absorption is completed, residual hydrogen is discharged by a gas pump, a hydrogen conveying pipe is removed, a globe valve is closed, and the hoisting equipment takes out the solid hydrogen cylinder containing the solid magnesium hydride through the lifting ring. At this time, the solid hydrogen cylinder 2 is a sealed hydrogen storage container at normal temperature and pressure.

[00123]Step S4: The solid hydrogen cylinder that completes hydrogen absorption is transported to a required position by transportation equipment. Specifically, long-distance large-scale transportation can be carried out by sea, land and air. This process is a storage and transportation process at normal pressure and temperature.

[00124]Step S5: The solid hydrogen cylinder 2 after hydrogen absorption is hoisted into a hydrogen absorption module. Specifically, when the solid hydrogen cylinder is transported to an end where the hydrogen is needed, the hoisting equipment loads the solid hydrogen cylinder 2 with the solid magnesium hydride into heating equipment by the lifting ring, then the gas pipe is connected, and the globe valve 21 is opened.

[00125]Step S6: The heat exchanger in the hydrogen storage module and a hydrogen outlet pipeline are vacuumized, then the solid hydrogen cylinder 2 after hydrogen absorption is heated

to release hydrogen from the solid magnesium hydride, and the released hydrogen is stored by a hydrogen storage module to complete the hydrogen desorption process. Specifically, the intelligent heating equipment in the hydrogen storage module turns on different segments of heating modules based on the height of the solid hydrogen cylinder at a heating temperature of 400-550°C, and then the hydrogen is released. The hydrogen is conveyed to the heat exchanger by the gas pump 4 for cooling, and then is conveyed to a hydrogen storage tank 5. The hydrogen storage tank 5 outputs hydrogen outward. A first globe valve 7 is mounted on the hydrogen storage tank 5 for on/off control of hydrogen supply, and this process is the hydrogen desorption process. After the hydrogen desorption process is completed, the hydrogen is discharged, the gas pipe is disconnected, the globe valve 21 is closed, and the hoisting equipment takes out the solid hydrogen cylinder 2 with the solid magnesium by the lifting ring. In this case, the solid magnesium hydride in the solid hydrogen cylinder 2 has transformed into a solid metal magnesium ingot, the solid hydrogen cylinder 2 with the solid metal magnesium ingot is transported to a hydrogen absorption place for hydrogen absorption. In this way, a closed-loop cycle for transporting hydrogen is formed, and the transportation of hydrogen at normal temperature and pressure is completed.

[00126] Steps S1 to S6 are repeated to achieve cyclic hydrogen transportation at normal temperature and pressure.

[00127] In steps S3 and S6, in the process of heating the solid hydrogen cylinder by the intelligent heating equipment, when the intelligent control module sends out an emergency heat dissipation command, a pressurized gas supply source in a heat dissipation module is started, a pressurized heat dissipation gas enters through an air inlet hole 31 located on a thermal insulation bracket and is blown tangentially towards an entire circumference of a lower sidewall of the solid hydrogen cylinder, and the injected pressurized heat radiation gas ascends around a circumferential direction of the solid hydrogen cylinder and is ultimately discharged from the top of the solid hydrogen cylinder.

[00128] The device in the present disclosure is not only convenient to achieve modular arrangement and processing, but also can achieve intelligent automation in each processing link, and the hydrogen absorption and desorption process is safe and reliable, which ensures the purity and stability of hydrogen. After the magnesium ingot 28 in the solid hydrogen cylinder 2 is heated by heating equipment at the hydrogen absorption place and hydrogen is introduced into the solid hydrogen cylinder, the magnesium ingot 28 reacts with the hydrogen to obtain solid magnesium hydride, thereby completing hydrogen absorption process. The solid hydrogen cylinder 2 at normal temperature and pressure is transported to a hydrogen release place, and then the hydrogen is released by the heating equipment. At this time, the solid magnesium hydride is transformed into

the magnesium ingot 28. The solid hydrogen cylinder 2 stored with the magnesium ingot 28 is returned to the hydrogen absorption place for continuous hydrogen absorption. In this way, the purpose of cyclic hydrogen transportation is implemented through the circulation of the solid hydrogen cylinder 2.

[00129] The present disclosure provides a cyclic method and equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure. Based on optimal design of solid magnesium hydride in each link of hydrogen absorption, hydrogen desorption, hydrogen storage and hydrogen transportation, hydrogen storage and transportation at normal temperature and pressure is achieved with safety and reliability, and the cost of each link is greatly reduced. Hydrogen transportation at normal temperature and pressure can be completed for many times by filling the magnesium ingot 28 at one time, which greatly improves the safety and reduces the cost, and is beneficial to the industrialization and large-scale transportation of solid hydrogen storage. The present disclosure overcomes the constraints of transportation distance and end-user deployment scale for hydrogen, thereby pioneering a new pathway for popularizing the utilization of hydrogen energy.

[00130] First of all, it should be noted here that "inward" is a direction towards the center of an accommodation space, and "outward" is a direction away from the center of the accommodation space.

[00131] In the description of the present disclosure, it should be understood that the orientation or positional relationship indicated by terms "center", "longitudinal", "transverse", "length", "width", "thickness", "upper", "lower", "front", "back", "left", "right", "vertical", "horizontal", "top", "bottom", "inside", "outside", "clockwise", "counterclockwise", "axial", "radial" and "peripheral" is based on the orientation or positional relationship shown in the drawings only for convenience of description of the present disclosure and simplification of description rather than indicating or implying that the device or element referred to must have a particular orientation, be constructed and operate in a particular orientation, and thus are not to be construed as limiting the present disclosure.

[00132] Furthermore, the terms "first" and "second" are used for descriptive purposes only and are not to be construed as indicating or implying relative importance or implying the number of the indicated technical features. Thus, the feature defined by "first" and "second" can explicitly or implicitly include one or more features. In the description of the present disclosure, "a plurality of" means at least two, such as two, three and more, unless otherwise specifically defined.

[00133] In the present disclosure, unless expressly specified and limited otherwise, the terms "install", "couple", "connect" and "fix" should be interpreted broadly. For example, a connection

may be a fixed connection, a detachable connection, or an integrated connection. A connection may be a mechanical connection, or electrical connection. A connection may be a direct connection, an indirect connection via an intermediate medium, a communication of insides of two elements, or interaction of two elements. For those of ordinary skill in the art, the specific meanings of the foregoing terms in the present disclosure can be understood on a case-by-case basis.

[00134] In the present disclosure, unless otherwise specified and limited, a first feature above or below a second feature may include that the first feature is in direct contact with the second feature, or may include that the first feature and the second feature are in contact with each other through other features therebetween rather than direct contact. Moreover, the first feature "above", "on" and "over" the second feature includes that the first feature is above and at an inclined top of the second feature, or only indicates that a horizontal height of the first feature is higher than that of the second feature. The first feature "below", "under" and "beneath" the second feature includes that the first feature is below and at an inclined bottom of the second feature, or only indicates that a horizontal height of the first feature is lower than that of the second feature.

[00135] In the description of this specification, descriptions referring to the terms "one embodiment", "some embodiments", "examples", "specific examples" or "some examples" mean that specific features, structures, materials or characteristics described in conjunction with this embodiment or example are included in at least one embodiment or example of the present disclosure. In this specification, the schematic representations of the foregoing terms are not necessarily aimed at a same embodiment or example. Moreover, specific features, structures, materials or characteristics described may be combined in any one or more embodiments or examples in a suitable manner. In addition, those skilled in the art can bind and combine different embodiments or examples and features of different embodiments or examples described in this specification without contradicting each other.

[00136] The foregoing is merely a preferred embodiment of the present disclosure, the scope of protection of the present disclosure is not limited to the foregoing embodiments, and variations or substitutions capable of being easily thought by those of ordinary skill in the art within the scope of the disclosure of the present disclosure should be encompassed within the scope of protection of the present disclosure. Therefore, the scope of protection of the present disclosure shall various modifications and embellishments made without departing from the principle of the present disclosure shall be subject to the scope of protection of the claims.

CLAIMS

WHAT IS CLAIMED IS:

1. Cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure, comprising a solid hydrogen cylinder, a hydrogen absorption module, and a hydrogen storage module, wherein

the solid hydrogen cylinder is made of stainless steel, and a magnesium ingot is placed in the solid hydrogen cylinder;

the hydrogen absorption module and the hydrogen storage module are both of modular design structures, and comprise intelligent heating equipment, and the intelligent heating equipment is configured to heat the solid hydrogen cylinder for hydrogen absorption or desorption;

the intelligent heating equipment comprises a human-machine interaction module, an intelligent control module, a power module, a heating module, a nano thermal insulation module, a temperature detection module, and a heat dissipation module, wherein

the human-machine interaction module comprises a visible digital model and a touch screen, the visible digital model is configured to display an operating condition of the intelligent heating equipment, and the touch screen is configured to control the intelligent heating equipment to adjust a heating temperature, a pressure and a heating sequence, thereby achieving speed control of hydrogen absorption and desorption;

the intelligent control module is electrically connected to the human-machine interaction module, the heating module, the temperature detection module and the heat dissipation module, and configured to achieve automatic control of the intelligent heating equipment;

the power module is electrically connected to the intelligent control module, the human-machine interaction module, the heating module, the temperature detection module and the heat dissipation module;

the heating module comprises a mica high-temperature copper wire and a power supply wire; the mica high-temperature copper wire is wound outside the nano thermal insulation module, and the power supply wire is connected to the mica high-temperature copper wire; when the mica high-temperature copper wire is electrified to generate a magnetic field, the magnetic field generates an eddy current in the solid hydrogen cylinder to form self-heating;

the nano thermal insulation module comprises a thermal insulation bracket made of a non-metallic thermal insulation material and a nano thermal insulation material made of a nano-microporous material; the solid hydrogen cylinder is placed in the thermal insulation bracket, and a non-metallic thermal insulation layer is formed by the thermal insulation bracket; a gap is left between the solid hydrogen cylinder and an inner wall of the thermal insulation bracket to form a static air insulation layer; the nano thermal insulation material is wound outside the thermal insulation bracket to form a nano thermal insulation layer;

the temperature detection module is mounted outside the nano thermal insulation module, and is in contact connection with the solid hydrogen cylinder in a spring probe manner to test a temperature of the solid hydrogen cylinder in real time;

the heat dissipation module is arranged in the thermal insulation bracket, and located at a lower portion of the solid hydrogen cylinder; the heat dissipation module comprises air inlet holes formed in the thermal insulation bracket and a pressurized gas supply source connected to the air inlet hole; the air inlet holes are arranged around an entire circumference of the solid hydrogen cylinder, and an outlet axis of the air inlet hole is tangent to a pipe wall of the solid hydrogen cylinder.

2. The cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to claim 1, wherein the heating module is arranged in a segmented structure along a vertical height direction, and each segment of the heating module is capable of being controlled independently controlled to accommodate solid-state hydrogen cylinders with different heights.

3. The cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to claim 1, wherein the temperature detection modules are mounted at an upper portion, a middle portion and a lower portion of the nano thermal insulation module, respectively.

4. The cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to claim 1, wherein the hydrogen absorption module comprises a hydrogen storage tank, a gas pump, intelligent heating equipment, a tee valve, and a switch valve;

the hydrogen storage tank is connected to the gas pump through the switch valve to supply

hydrogen;

the gas pump is connected to the solid hydrogen cylinder through the tee valve to vacuumize the cylinder; and

the intelligent heating equipment is in contact connection with the solid hydrogen cylinder for heating the solid hydrogen cylinder.

5. The cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to claim 1, wherein the hydrogen storage module comprises a hydrogen storage tank, a gas pump, intelligent heating equipment, a heat exchanger, a tee valve, and a switch valve;

the hydrogen storage tank is connected to the gas pump through the switch valve;

the solid hydrogen cylinder is connected to the heat exchanger through the tee valve for hydrogen output;

the gas pump is connected to the heat exchanger and the tee valve; and

the intelligent heating equipment is in contact connection with the solid hydrogen cylinder for heating the solid hydrogen cylinder.

6. The cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to claim 1, wherein the solid hydrogen cylinder comprises a solid hydrogen cylinder body, an end cover, a globe valve, a support bracket, and a magnesium ingot, wherein

the solid hydrogen cylinder body is of a sealed tank structure with an open top;

the open top is covered with the end cover to form an integrally sealed solid hydrogen cylinder;

the globe valve is mounted at an inlet/outlet of the end cover;

the support bracket is mounted in the solid hydrogen cylinder body; and

the magnesium ingot is placed on the support bracket.

7. The cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to claim 6, wherein the solid hydrogen cylinder further comprises a bottom anti-collision sleeve and a valve body protection sleeve, wherein

the bottom anti-collision sleeve is sleeved at the bottom of the solid hydrogen cylinder body; and

the valve body protection sleeve is sleeved outside the globe valve.

8. The cyclic equipment for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure according to claim 6, wherein

the solid hydrogen cylinder further comprises a sealing washer, a mounting bolt, an eyebolt, a safety valve, and a deflation valve;

the sealing washer is arranged at a joint of the end cover and the solid hydrogen cylinder body;

the mounting bolt and the eyebolt are used to connect the end cover and the solid hydrogen cylinder body; and

the safety valve and the deflation valve are arranged on a gas pipe connected to the globe valve in turn.

9. A cyclic method for solid hydrogen-based hydrogen storage and transportation at normal temperature and pressure, wherein the equipment according to any one of claims 1 to 8 is used for performing the cyclic method, and the method comprises the following steps:

step S1, hoisting a solid hydrogen cylinder into intelligent heating equipment in a hydrogen absorption module;

step S2, vacuumizing the solid hydrogen cylinder;

step S3, supplying hydrogen into the solid hydrogen cylinder, and supplying power to a mica high-temperature copper wire at the same time to generate a magnetic field, wherein the magnetic field generates an eddy current in the solid hydrogen cylinder made of stainless steel after passing through a nano thermal insulation module; enabling the stainless-steel solid hydrogen cylinder to start self-heating under an own resistance condition, making a magnesium ingot placed in the solid hydrogen cylinder react with hydrogen to generate solid magnesium hydride to complete a hydrogen absorption process, specifically, introducing the hydrogen into the solid hydrogen cylinder, transmitting, by a pressure sensor, a signal to the intelligent heating equipment when a pressure reaches 1 MPa, wherein the intelligent heating equipment turns on an appropriate number of heating module segments according to a height of the solid hydrogen cylinder, wherein and the magnesium ingot reacts with the hydrogen at 380-480°C to generate magnesium hydrate; after the hydrogen absorption is completed, discharging residual hydrogen by a gas pump, removing a hydrogen conveying pipe, closing a globe valve, and taking out, by hoisting equipment, the solid hydrogen cylinder containing the solid magnesium hydride through a lifting ring;

step S4, transporting the solid hydrogen cylinder that completes hydrogen absorption to a required position;

step S5, hoisting the solid hydrogen cylinder after hydrogen absorption into a hydrogen storage module; and

step S6, vacuumizing a heat exchanger in the hydrogen storage module and a hydrogen outlet pipeline, then heating the solid hydrogen cylinder after hydrogen absorption to release the hydrogen from the solid magnesium hydride, storing the released hydrogen by the hydrogen storage module to complete a hydrogen desorption process, specifically, turning on, by intelligent heating equipment in the hydrogen storage module, different segments of the heating modules according to a height of the solid hydrogen cylinder, with a heating temperature of 400-550°C, and releasing the hydrogen; conveying, by the gas pump, the hydrogen to the heat exchanger for cooling, and then conveying the hydrogen to a hydrogen storage tank, wherein the hydrogen storage tank outputs the hydrogen to the outside to complete the hydrogen desorption process; and after the hydrogen is discharged, disconnecting a gas pipe, closing the globe valve, taking out, by hoisting equipment, the solid hydrogen cylinder containing solid magnesium through a lifting ring; and repeating steps S1-S6 to achieve cyclic hydrogen transportation at normal temperature and pressure, wherein

in steps S3 and S6, in the process of heating the solid hydrogen cylinder by the intelligent heating equipment, when the intelligent control module sends out an emergency heat dissipation command, a pressurized gas supply source in a heat dissipation module is started, a pressurized heat dissipation gas enters through an air inlet hole located on a thermal insulation bracket and is blown tangentially towards an entire circumference of a lower sidewall of the solid hydrogen cylinder, and the injected pressurized heat radiation gas rises around a circumferential direction of the solid hydrogen cylinder and is ultimately discharged from the top of the solid hydrogen cylinder.