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Hydrogen compression system

Abstract

A hydrogen compression system includes: a heat pump part including a heat pump line configured to allow a refrigerant to circulate therethrough, a hydrogen compression part configured to compress hydrogen by being repeatedly heated and cooled, a first circulation line connected to the heat pump line while passing through the hydrogen compression part and configured to allow the refrigerant introduced from the heat pump line to circulate therethrough, a second circulation line provided to pass through the hydrogen compression part and configured to allow a cooling fluid to circulate therethrough, and a cooling unit provided in the second circulation line and configured to cool the cooling fluid, in which the hydrogen compression part is heated by the refrigerant or cooled by the cooling fluid, thereby minimizing electric power consumption and improving energy efficiency.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

(1) This application claims priority to and the benefit of Korean Patent Application No. 10-2022-0148796, filed in the Korean Intellectual Property Office on Nov. 9, 2022, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

(2) Embodiments of the present disclosure relate to a hydrogen compression system, and more particularly, to a hydrogen compression system capable of minimizing electric power consumption and improving energy efficiency when compressing hydrogen by using a thermochemical method.

BACKGROUND

(3) The statements in this section merely provide background information related to the present disclosure and may not constitute prior art.

(4) Hydrogen may be produced by hydrogen production facilities using steam reforming, water electrolysis, coal gasification, biomass gasification, and other fossil fuel-based methods such as a thermochemical process.

(5) Meanwhile, because hydrogen extracted (produced) in the hydrogen production facility has a low pressure (e.g., 10 bar or less), it is difficult to store the hydrogen directly in a high-pressure storage facility such as a high-pressure tank. Therefore, hydrogen extracted (produced) in the hydrogen production facility needs to be compressed by a separate compression facility.

(6) Examples of a method of compressing hydrogen include a method of compressing hydrogen in a mechanical manner and a method of compressing hydrogen in a non-mechanical manner. In the related art, there has been a proposed facility for compressing hydrogen without the use of mechanical means. This facility utilizes a thermochemical compressor based on metal hydride (namely, a metal hydride-based thermochemical compressor”) to compress the hydrogen.

(7) Unlike a mechanical compressor (e.g., a reciprocating compressor), the thermochemical compressor may compress hydrogen without a separate mechanical component (e.g., a piston configured to reciprocate). Therefore, it is possible to simplify the structure of the compressor and improve a degree of design freedom and spatial utilization. Further, the thermochemical compressor may cause less noise and be easily maintained and repaired because the cycle for replacing various types of components abraded by rotating devices is long. In addition, the mechanical compressor often contaminates hydrogen because the mechanical compressor uses lubricating oil. In contrast, the thermochemical hydrogen compressor releases hydrogen by breaking chemical bonds in the form of metal hydride without the use of lubricating oil, which makes it possible to maintain high-purity hydrogen.

(8) The thermochemical compressor may compress hydrogen through a process of repeatedly heating and cooling a metal hydride material by using characteristics of the metal hydride material. An equilibrium pressure of a reaction for making metal hydride by storing hydrogen in metal varies depending on the composition and temperature of the material. In general, the equilibrium pressure increases as the temperature increases. Therefore, when hydrogen, which is introduced at a low temperature and a low pressure, forms metal hydride, the temperature is increased and then hydrogen is compressed through a process in which high-pressure hydrogen is released from metal hydride. As described above, to compress hydrogen by heating a metal hydride material, a separate electric heat source (e.g., an electric heater) needs to be provided, and the metal hydride material needs to be heated by heat transferred from the electric heat source to the metal hydride material by conduction. For this reason, there is a problem in that electric power consumption increases and energy efficiency decreases.

SUMMARY

(9) The present disclosure has been made in an effort to provide a hydrogen compression system capable of minimizing electric power consumption and improving energy efficiency when compressing hydrogen by using a thermochemical method.

(10) Particularly, the present disclosure has been made in an effort to operate a metal hydride compressor by using a refrigerant of a heat pump part as a heat source.

(11) The present disclosure has also been made in an effort to continuously extract high-pressure hydrogen.

(12) The objects to be achieved by the embodiments are not limited to the above-mentioned

objects, but also include objects or effects that may be understood from the solutions or embodiments described below.

(13) An embodiment of the present disclosure provides a hydrogen compression system. The hydrogen compression system includes: a heat pump part including a heat pump line configured to allow a refrigerant to circulate therethrough; a hydrogen compression part configured to compress hydrogen by being repeatedly heated and cooled; and a first circulation line connected to the heat pump line while passing through the hydrogen compression part and configured to allow the refrigerant introduced from the heat pump line to circulate therethrough. The hydrogen compression system further includes: a second circulation line provided to pass through the hydrogen compression part and configured to allow a cooling fluid to circulate therethrough; and a cooling unit provided in the second circulation line and configured to cool the cooling fluid, in which the hydrogen compression part is heated by the refrigerant or cooled by the cooling fluid.

(14) This is to minimize electric power consumption required for a process of compressing hydrogen by using a thermochemical method and to improve energy efficiency.

(15) In the related art, to compress hydrogen by using the thermochemical method, a separate electric heat source (e.g., an electric heater) for heating the metal hydride material needs to be provided, and the metal hydride material needs to be heated by heat transferred from the electric heat source to the metal hydride material by conduction. For this reason, there is a problem in that electric power consumption increases and energy efficiency decreases.

(16) In contrast, according to the embodiment of the present disclosure, the hydrogen compression part configured to compress hydrogen by using a thermochemical method may be heated or cooled by the refrigerant and the cooling fluid of the heat pump part, such that the hydrogen compression part may be operated (heated and cooled) to compress hydrogen even without using a separate electric heat source (e.g., an electric heater) that consumes a large amount of electric power. Therefore, it is possible to obtain an advantageous effect of minimizing electric power consumption and remarkably improving energy efficiency (for example, by 50%) in comparison with a method that heats a hydrogen compression part by using an electric heat source.

(17) The heat pump part may have various structures capable of converting thermal energy of a low-temperature object (e.g., the refrigerant) into high-temperature thermal energy by supplying mechanical energy from the outside.

(18) According to an embodiment of the present disclosure, the heat pump part may include: a compressor provided in the heat pump line and configured to compress the refrigerant; a condenser provided in the heat pump line and configured to condense the refrigerant; an expansion valve provided in the heat pump line and configured to decompress the refrigerant; and an evaporator provided in the heat pump line and configured to vaporize the refrigerant, and the first circulation line may be connected to the condenser or the evaporator.

(19) According to an embodiment of the present disclosure, the hydrogen compression part may include a first compression part configured to compress hydrogen, and a second compression part configured to compress hydrogen independently of the first compression part. The first and second compression parts may alternately compress hydrogen by being alternately heated or cooled.

(20) As described above, the first and second compression parts may alternately compress hydrogen as the first and second compression parts are alternately heated or cooled. Therefore, it is possible to continuously perform the process of compressing hydrogen without interruption.

(21) According to another embodiment of the present disclosure, the hydrogen compression system may include: a first bypass line having one end disposed at an upstream side of the first compression part and connected to the first circulation line, and the other end disposed at an upstream side of the second compression part and connected to the second circulation line. The hydrogen compression system may further include: a second bypass line having one end disposed at a downstream side of the second compression part and connected to the second circulation line, and the other end disposed at a downstream side of the first compression part and connected to the

first circulation line. The hydrogen compression system may further include: a third bypass line having one end disposed at the upstream side of the second compression part and connected to the second circulation line, and the other end disposed at the upstream side of the first compression part and connected to the first circulation line. The hydrogen compression system may further include: a fourth bypass line having one end disposed at the downstream side of the first compression part and connected to the first circulation line, and the other end disposed at the downstream side of the second compression part and connected to the second circulation line.
(22) According to an embodiment of the present disclosure, the hydrogen compression system may include: a first valve provided in the first circulation line and configured to selectively switch a flow path of the refrigerant introduced from the heat pump line to the first bypass line; and a second valve provided in the second circulation line and configured to selectively switch a flow path of the refrigerant having passed through the second compression part to the second bypass line. The hydrogen compression system may further include: a third valve provided in the second circulation line and configured selectively switch a flow path of the cooling fluid having passed through the cooling unit to the third bypass line; and a fourth valve provided in the first circulation line and configured to selectively switch a flow path of the cooling fluid having passed through the first compression part to the fourth bypass line.
(23) According to an embodiment of the present disclosure, the first compression part may include a first-first metal hydride compressor configured to compress hydrogen, and a first-second metal hydride compressor configured to compress hydrogen independently of the first-first metal hydride compressor.
(24) According to another embodiment of the present disclosure, the first-first metal hydride compressor and the first-second metal hydride compressor may be connected in series.
(25) According to one embodiment of the present disclosure, the second compression part may include a second-first metal hydride compressor configured to compress hydrogen, and a second-second metal hydride compressor configured to compress hydrogen independently of the second-first metal hydride compressor.
(26) According to one embodiment of the present disclosure, the second-first metal hydride compressor and the second-second metal hydride compressor may be connected in series.
(27) According to one embodiment of the present disclosure, the hydrogen compression system may include: a first heater provided in the first circulation line, positioned between the first valve and the first compression part, and configured to heat the refrigerant; and a second heater provided in the second circulation line, positioned between the third valve and the second compression part, and configured to heat the refrigerant.
(28) As described above, in the embodiment of the present disclosure, the first and second heaters may be respectively provided in the first and second circulation lines, and the first and second heaters may additionally heat the refrigerant to be supplied to the first and second compression parts at the time of heating the first and second compression parts. Therefore, it is possible to obtain an advantageous effect of increasing the heating capacity and heating speed of the first and second compression parts.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a view illustrating a hydrogen compression system according to an embodiment of the present disclosure.
(2) FIG. **2** is a view illustrating a process of heating a first compression part, and a process of cooling a second compression part of the hydrogen compression system according to an embodiment of the present disclosure.

(3) FIG. **3** is a view illustrating a process of cooling the first compression part, and a process of heating the second compression part of the hydrogen compression system according to an embodiment of the present disclosure.
(4) The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.

DETAILED DESCRIPTION

(5) Hereinafter, embodiments of the present disclosure are described in detail with reference to the accompanying drawings.
(6) However, the technical spirit of the present disclosure is not limited to some embodiments described herein but may be implemented in various different forms. One or more of the constituent elements in the embodiments may be selectively combined and substituted for use within the scope of the technical spirit of the present disclosure.
(7) In addition, unless otherwise specifically and explicitly defined and stated, the terms (including technical and scientific terms) used in the embodiments of the present disclosure may be construed as the meaning which may be commonly understood by the person with ordinary skill in the art to which the present disclosure pertains. The meanings of the commonly used terms such as the terms defined in dictionaries may be interpreted in consideration of the contextual meanings of the related technology.
(8) In addition, the terms used in the embodiments of the present disclosure are for explaining the embodiments, not for limiting the present disclosure.
(9) In the present specification, unless particularly stated otherwise, a singular form may also include a plural form. The expression “at least one (or one or more) of A, B, and C” may include one or more of all combinations that can be made by combining A, B, and C.
(10) In addition, the terms such as first, second, A, B, (a), and (b) may be used to describe constituent elements of the embodiments of the present disclosure.
(11) These terms are used only for the purpose of discriminating one constituent element from another constituent element, and the nature, the sequences, or the orders of the constituent elements are not limited by the terms.
(12) Further, when one constituent element is described as being ‘connected’, ‘coupled’, or ‘attached’ to another constituent element, one constituent element may be connected, coupled, or attached directly to another constituent element or connected, coupled, or attached to another constituent element through still another constituent element interposed therebetween. When a component, device, element, or the like of the present disclosure is described as having a purpose or performing an operation, function, or the like, the component, device, or element should be considered herein as being “configured to” meet that purpose or to perform that operation or function.
(13) In addition, the expression “one constituent element is provided or disposed above (on) or below (under) another constituent element” includes not only a case in which the two constituent elements are in direct contact with each other, but also a case in which one or more other constituent elements are provided or disposed between the two constituent elements. The expression “above (on) or below (under)” may mean a downward direction as well as an upward direction based on one constituent element.
(14) Referring to FIGS. **1** to **3**, a hydrogen compression system **10** according to an embodiment of the present disclosure includes: a heat pump part **100** including a heat pump line **102** and configured to allow a refrigerant to circulate therethrough; a hydrogen compression part **300** configured to compress hydrogen by being repeatedly heated and cooled; a first circulation line **410** connected to the heat pump line **102** while passing through the hydrogen compression part **300** and configured to allow the refrigerant introduced from the heat pump line **102** to circulate therethrough; a second circulation line **420** configured to pass through the hydrogen compression part **300** and allow a cooling fluid to circulate therethrough; and a cooling unit provided in the

second circulation line **420** and configured to cool the cooling fluid. The hydrogen compression part **300** may be heated by the refrigerant or cooled by the cooling fluid.
(15) For reference, the hydrogen compression system **10** according to the present disclosure may be used to treat (compress) required hydrogen. The present disclosure is not restricted or limited by the characteristics and states of hydrogen treated by the hydrogen compression system **10**.
(16) According to the embodiment of the present disclosure, the hydrogen compression system **10** may be used to compress hydrogen, produced by a steam reforming method (or water electrolysis), before the hydrogen is supplied to a supply destination (e.g., a high-pressure tank). According to another embodiment of the present disclosure, the hydrogen compression system may be used to compress again hydrogen that has been compressed once.
(17) The heat pump part **100** may include the heat pump line **102** through which the refrigerant circulates. The refrigerant circulating through the heat pump line **102** may be used as a heat medium for heating the hydrogen compression part **300**.
(18) The heat pump part **100** may have various structures capable of converting thermal energy of a low-temperature object (e.g., the refrigerant) into high-temperature thermal energy by supplying mechanical energy from the outside. The present disclosure is not restricted or limited by the type and structure of the heat pump part **100**.
(19) According to the embodiment of the present disclosure, the heat pump part **100** may include: a compressor **110** provided in the heat pump line **102** and configured to compress the refrigerant; a condenser **120** provided in the heat pump line **102** and configured to condense the refrigerant; an expansion valve **130** provided in the heat pump line **102** and configured to decompress the refrigerant; and an evaporator **140** provided in the heat pump line **102** and configured to vaporize the refrigerant.
(20) For example, the refrigerant may circulate through the heat pump line **102** while sequentially passing through the compressor **110**, the condenser **120**, the expansion valve **130**, and the evaporator **140**. According to another embodiment of the present disclosure, the refrigerant may circulate through the heat pump line while sequentially passing through the compressor, the evaporator, the expansion valve, and the condenser.
(21) The compressor **110** is configured to compress the low-pressure refrigerant into the high-pressure refrigerant. The present disclosure is not restricted or limited by the type and structure of the compressor **110**.
(22) The condenser **120** is a kind of heat exchanger configured to condense the high-temperature, high-pressure refrigerant by exchanging heat with air (or water). The present disclosure is not restricted or limited by the type and structure of the condenser **120**.
(23) The expansion valve **130** is a kind of decompression valve configured to reduce a pressure of the refrigerant having passed through the condenser **120** and adjust a flow rate of the refrigerant. The present disclosure is not restricted or limited by the type and structure of the expansion valve **130**.
(24) The evaporator **140** is also a kind of heat exchanger configured to vaporize the refrigerant by exchanging heat with air (or water). The present disclosure is not restricted or limited by the type and structure of the evaporator **140**.
(25) The hydrogen compression part **300** is configured to compress hydrogen by being repeatedly heated and cooled.
(26) The hydrogen compression part **300** may have various structures capable of compressing hydrogen by being repeatedly heated and cooled. The present disclosure is not restricted or limited by the structure of the hydrogen compression part **300**.
(27) For reference, in the embodiment of the present disclosure, the hydrogen compression part **300** may be defined as the hydrogen compression part **300** that does not include a separate electric heat source (e.g., an electric heater) for heating metal hydride compressors.
(28) According to an embodiment of the present disclosure, the hydrogen compression part **300**

may include a first compression part **310** configured to compress hydrogen, and a second compression part **320** configured to compress hydrogen independently of the first compression part **310**. The first and second compression parts **310** and **320** may alternately compress hydrogen by being alternately heated or cooled.

(29) According to another embodiment of the present disclosure, the hydrogen compression part may include three or more compression parts. Alternatively, the hydrogen compression part may include only one compression part.

(30) According to another embodiment of the present disclosure, the first compression part **310** may include a first-first metal hydride compressor **312** configured to compress hydrogen, and a first-second metal hydride compressor **314** configured to compress hydrogen independently of the first-first metal hydride compressor **312**.

(31) In one form, the first-first metal hydride compressor **312** and the first-second metal hydride compressor **314** may be connected in series. For example, the first-second metal hydride compressor **314** may be connected in series to a downstream side of the first-first metal hydride compressor **312**.

(32) According to another embodiment of the present disclosure, the first-first metal hydride compressor and the first-second metal hydride compressor may be connected in parallel.

(33) In addition, according to an embodiment of the present disclosure, the second compression part **320** may include a second-first metal hydride compressor **322** configured to compress hydrogen, and a second-second metal hydride compressor **324** configured to compress hydrogen independently of the second-first metal hydride compressor **322**.

(34) In one form, the second-first metal hydride compressor **322** and the second-second metal hydride compressor **324** may be connected in series. For example, the second-second metal hydride compressor **324** may be connected in series to a downstream side of the second-first metal hydride compressor **322**.

(35) According to another embodiment of the present disclosure, the second-first metal hydride compressor and the second-second metal hydride compressor may be connected in parallel.

(36) Each of the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**), which constitute the hydrogen compression part **300**, is a metal hydride-based thermochemical compressor and may compress hydrogen by being repeatedly heated and cooled by using properties of a metal hydride material.

(37) For example, the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**) of the hydrogen compression part **300** may have various structures and shapes each having a storage space therein. The present disclosure is not restricted or limited by the structure and shape of the metal hydride compressor.

(38) The type of metal hydride material, which constitutes each of the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**) of the hydrogen compression part **300** may be variously changed in accordance with required conditions and design specifications.

(39) For example, the metal hydride material may include at least one of an AB5-based alloy, an AB2-based alloy, or an AB-based alloy. For example, the metal hydride material may be an alloy containing LaNi.sub.5, TiFe, TiMn.sub.2, and the like as main elements.

(40) For reference, the metal hydride material may be provided in the form of powder or pellets and accommodated in a container (not illustrated). The present disclosure is not restricted or limited by the accommodated state and shape of the metal hydride material. According to another embodiment of the present disclosure, the metal hydride material may be formed by compressing metal hydride powder or metal hydride pellets and have a bulk shape corresponding to the container.

(41) The first circulation line **410** may be connected to the heat pump line **102** while passing through the hydrogen compression part **300**. The refrigerant introduced from the heat pump line **102** may circulate through the first circulation line **410**.
(42) For example, the first circulation line **410** may be connected to the condenser **120** or the evaporator **140** through which the high-temperature refrigerant may flow.
(43) In one embodiment, both ends (e.g., first and second ends) of the first circulation line **410** are connected to the condenser **120**. With the above-mentioned structure, the high-temperature refrigerant discharged from the compressor **110** may circulate through the first circulation line **410** via the condenser **120** and then circulate through the heat pump line **102** via the condenser **120**.
(44) For reference, in the embodiment of the present disclosure, the configuration in which the first circulation line **410** passes through the hydrogen compression part **300** may mean that the first circulation line **410** is provided to exchange heat with (to heat) the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**) that constitute the hydrogen compression part **300**.
(45) For example, the first circulation line **410** may pass through interiors of the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**) or surround the metal hydride compressors.
(46) According to the embodiment of the present disclosure, the refrigerant supplied through the first circulation line **410** may heat the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**) through heat exchange by convection.
(47) The refrigerant circulating through the first circulation line **410** may be used as a heat medium for heating the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**).
(48) The second circulation line **420** may pass through the hydrogen compression part **300**, and the cooling fluid may circulate through the second circulation line **420**.
(49) The second circulation line **420** may have various structures capable of passing through the hydrogen compression part **300**. The present disclosure is not restricted or limited by the structure and shape of the second circulation line **420**.
(50) In the embodiment of the present disclosure, the configuration in which the second circulation line **420** passes through the hydrogen compression part **300** may mean that the second circulation line **420** is provided to exchange heat with (to cool) the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**) that constitute the hydrogen compression part **300**.
(51) For example, the second circulation line **420** may pass through the interiors of the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**) or surround the metal hydride compressors.
(52) According to the embodiment of the present disclosure, the cooling fluid supplied through the second circulation line **420** may cool the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**) through heat exchange by convection.
(53) The cooling fluid circulating through the second circulation line **420** may be used to cool the metal hydride compressors (the first-first metal hydride compressor **312**, the first-second metal

hydride compressor **314**, the second-first metal hydride compressor **322**, and the second-second metal hydride compressor **324**).
(54) For reference, a typical liquid (e.g., coolant) or gas may be used as the cooling fluid. The present disclosure is not restricted or limited by the type and properties of the cooling fluid.
(55) The cooling unit is provided in the second circulation line **420** and configured to cool the cooling fluid.
(56) Various cooling means capable of cooling the cooling fluid may be used as the cooling unit. The present disclosure is not restricted or limited by the type and structure (method) of the cooling unit.
(57) For example, the cooling unit may be configured to cool the cooling fluid in a water-cooled manner (or air-cooled manner). According to another embodiment of the present disclosure, the cooling unit may be configured by using a Peltier element or other cooling means.
(58) As described above, according to the embodiment of the present disclosure, the first and second compression parts **310** and **320** are configured to alternately compress hydrogen by being alternately heated or cooled.
(59) For example, the second compression part **320** may be cooled while the first compression part **310** is heated (hydrogen is compressed). On the contrary, the first compression part **310** may be cooled while the second compression part **320** is heated (hydrogen is compressed).
(60) As described above, the first and second compression parts **310** and **320** may alternately compress hydrogen as the first and second compression parts **310** and **320** are alternately heated or cooled. Therefore, it is possible to continuously perform the process of compressing hydrogen without interruption.
(61) In one embodiment for alternately heating and cooling the first and second compression parts **310** and **320**, the hydrogen compression system **10** may include: a first bypass line **430** having one end disposed at an upstream side of the first compression part **310** and connected to the first circulation line **410**, and the other end disposed at an upstream side of the second compression part **320** and connected to the second circulation line **420**; and a second bypass line **440** having one end disposed at a downstream side of the second compression part **320** and connected to the second circulation line **420**, and the other end disposed at a downstream side of the first compression part **310** and connected to the first circulation line **410**. The hydrogen compression system **10** may further include a third bypass line **450** having one end disposed at the upstream side of the second compression part **320** and connected to the second circulation line **420**, and the other end disposed at the upstream side of the first compression part **310** and connected to the first circulation line **410**; and a fourth bypass line **460** having one end disposed at the downstream side of the first compression part **310** and connected to the first circulation line **410**, and the other end disposed at the downstream side of the second compression part **320** and connected to the second circulation line **420**.
(62) The first bypass line **430** is configured to supply the second circulation line **420** (the second compression part) with the refrigerant (the high-temperature refrigerant) that circulates through the first circulation line **410**.
(63) For example, one end of the first bypass line **430** may be disposed at the upstream side of the first compression part **310** (e.g., between the condenser **120** and an inlet end of the first compression part **310**) and connected to the first circulation line **410**. The other end of the first bypass line **430** may be disposed at the upstream side of the second compression part **320** (e.g., between the cooling unit and an inlet end of the second compression part **320**) and connected to the second circulation line **420**.
(64) The second bypass line **440** is configured to return the refrigerant having passed through the second compression part **320** to the first circulation line **410** (the heat pump line).
(65) For example, one end of the second bypass line **440** may be disposed at the downstream side of the second compression part **320** (e.g., between an outlet end of the second compression part **320**

and the cooling unit) and connected to the second circulation line **420**. The other end of the second bypass line **440** may be disposed at the downstream side of the first compression part **310** (e.g., between an outlet end of the first compression part **310** and the condenser **120**) and connected to the first circulation line **410**.
(66) The third bypass line **450** is configured to supply the first circulation line **410** (the first compression part) with the cooling fluid that circulates through the second circulation line **420**.
(67) For example, one end of the third bypass line **450** may be disposed at the upstream side of the second compression part **320** (e.g., between the cooling unit and the inlet end of the second compression part **320**) and connected to the second circulation line **420**. The other end of the third bypass line **450** may be disposed at the upstream side of the first compression part **310** (e.g., between the condenser **120** and the inlet end of the first compression part **310**) and connected to the first circulation line **410**.
(68) The fourth bypass line **460** is configured to return the refrigerant having passed through the first compression part **310** to the second circulation line **420** (the cooling unit).
(69) For example, one end of the fourth bypass line **460** may be disposed at the downstream side of the first compression part **310** (e.g., between the outlet end of the first compression part **310** and the condenser **120**) and connected to the first circulation line **410**. The other end of the fourth bypass line **460** may be disposed at the downstream side of the second compression part **320** (e.g., between the outlet end of the second compression part **320** and the cooling unit) and connected to the second circulation line **420**.
(70) According to another embodiment of the present disclosure, the hydrogen compression system **10** may include: a first valve **510** provided in the first circulation line **410** and configured to selectively switch the flow path of the refrigerant introduced from the heat pump line **102** to the first bypass line **430**; and a second valve **520** provided in the second circulation line **420** and configured to selectively switch the flow path of the refrigerant having passed through the second compression part **320** to the second bypass line **440**. The hydrogen compression system **10** may further include: a third valve **530** provided in the second circulation line **420** and configured to selectively switch the flow path of the cooling fluid having passed through the cooling unit to the third bypass line **450**; and a fourth valve **540** provided in the first circulation line **410** and configured to selectively switch the flow path of the cooling fluid having passed through the first compression part **310** to the fourth bypass line **460**.
(71) The first valve **510** may be provided in the first circulation line **410** and positioned between the condenser **120** and the inlet end of the first compression part **310**. The first bypass line **430** may be connected to the first valve **510**.
(72) Various valve means capable of selectively switching the flow path of the refrigerant introduced from the heat pump line **102** to the first bypass line **430** may be used as the first valve **510**.
(73) For example, a typical three-way valve may be used as the first valve **510**. More specifically, the first valve **510** may include: a first-first port **512** connected to the first circulation line **410** so that the refrigerant introduced from the heat pump line **102** is introduced into the first valve **510**; a first-second port **514** connected to the first circulation line **410** so that the refrigerant having passed through the first valve **510** is supplied to the first compression part **310**; and a first-third port **516** connected to one end of the first bypass line **430**.
(74) It is possible to selectively switch the flow path of the refrigerant introduced from the heat pump line **102** to the first bypass line **430** by selectively opening or closing the first-first port **512**, the first-second port **514**, and the first-third port **516** of the first valve **510**. In other words, referring to FIG. **2**, at the time of heating the first compression part **310** (cooling the second compression part **320**), when the first-first port **512** and the first-second port **514** are opened, and the first-third port **516** is closed, the refrigerant introduced from the heat pump line **102** may be supplied to the first compression part **310**. In contrast, as illustrated in FIG. **3**, at the time of heating the second

compression part **320** (cooling the first compression part **310**), when the first-first port **512** and the first-third port **516** are opened, and the first-second port **514** is closed, the supply of the refrigerant to the first compression part **310** may be cut off, and the refrigerant introduced from the heat pump line **102** may be supplied to the second compression part **320** through the first bypass line **430**.

(75) The second valve **520** may be provided in the second circulation line **420** and positioned between the outlet end of the second compression part **320** and the cooling unit. The second bypass line **440** may be connected to the second valve **520**.

(76) Various valve means capable of selectively switching the flow path of the refrigerant having passed through the second compression part **320** to the second bypass line **440** may be used as the second valve **520**.

(77) For example, a typical three-way valve may be used as the second valve **520**. More specifically, the second valve **520** may include: a second-first port **522** connected to the second circulation line **420** so that the refrigerant having passed through the second compression part **320** is introduced into the second valve **520**; a second-second port **524** connected to the second circulation line **420** so that the cooling fluid having passed through the second valve **520** is supplied to the cooling unit (the refrigerant having passed through the second compression part is not supplied to the cooling unit); and a second-third port **526** connected to one end of the second bypass line **440**.

(78) It is possible to selectively switch the flow path of the refrigerant having passed through the second compression part **320** to the second bypass line **440** by selectively opening or closing the second-first port **522**, the second-second port **524**, and the second-third port **526** of the second valve **520**. In other words, referring to FIG. **2**, at the time of heating the first compression part **310** (cooling the second compression part **320**), when the second-first port **522** and the second-second port **524** are opened, and the second-third port **526** is closed, the cooling fluid having passed through the second compression part **320** may be supplied to the cooling unit. In contrast, as illustrated in FIG. **3**, at the time of heating the second compression part **320** (cooling the first compression part **310**), when the second-first port **522** and the second-third port **526** are opened, and the second-second port **524** is closed, the refrigerant having passed through the second compression part **320** may be supplied back to the first circulation line **410** (the heat pump line) through the second bypass line **440**.

(79) The third valve **530** may be provided in the second circulation line **420** and positioned between the cooling unit and the inlet end of the second compression part **320**. The third bypass line **450** may be connected to the third valve **530**.

(80) Various valve means capable of selectively switching the flow path of the cooling fluid having passed through the cooling unit to the third bypass line **450** may be used as the third valve **530**.

(81) For example, a typical three-way valve may be used as the third valve **530**. More specifically, the third valve **530** may include: a third-first port **532** connected to the second circulation line **420** so that the cooling fluid having passed through the cooling unit is introduced into the third valve **530**; a third-second port **534** connected to the second circulation line **420** so that the cooling fluid having passed through the third valve **530** is supplied to the second compression part **320**; and a third-third port **536** connected to one end of the second bypass line **440**.

(82) It is possible to selectively switch the flow path of the cooling fluid having passed through the cooling unit to the third bypass line **450** by selectively opening or closing the third-first port **532**, the third-second port **534**, and the third-third port **536** of the third valve **530**. In other words, referring to FIG. **2**, at the time of heating the first compression part **310** (cooling the second compression part **320**), when the third-first port **532** and the third-second port **534** are opened, and the third-third port **536** is closed, the cooling fluid having passed through the cooling unit may be supplied to the second compression part **320**. In contrast, as illustrated in FIG. **3**, at the time of heating the second compression part **320** (cooling the first compression part **310**), when the third-first port **532** and the third-third port **536** are opened, and the third-second port **534** is closed, the

supply of the cooling fluid to the second compression part **320** may be cut off, and the cooling fluid having passed through the cooling unit may be supplied to the first compression part **310** through the third bypass line **450**.
(83) The fourth valve **540** may be provided in the first circulation line **410** and positioned between the outlet end of the first compression part **310** and the condenser **120**. The fourth bypass line **460** may be connected to the fourth valve **540**.
(84) Various valve means capable of selectively switching the flow path of the cooling fluid having passed through the first compression part **310** to the fourth bypass line **460** may be used as the fourth valve **540**.
(85) For example, a typical three-way valve may be used as the fourth valve **540**. More specifically, the fourth valve **540** may include: a fourth-first port **542** connected to the first circulation line **410** so that the cooling fluid having passed through the first compression part **310** is introduced into the fourth valve **540**; a fourth-second port **544** connected to the first circulation line **410** so that the refrigerant having passed through the fourth valve **540** is supplied to the condenser **120** (the cooling fluid having passed through the first compression part is not supplied to the condenser); and a fourth-third port **546** connected to one end of the fourth bypass line **460**.
(86) It is possible to selectively switch the flow path of the cooling fluid having passed through the first compression part **310** to the fourth bypass line **460** by selectively opening or closing the fourth-first port **542**, the fourth-second port **544**, and the fourth-third port **546** of the fourth valve **540**. In other words, referring to FIG. **2**, at the time of heating the first compression part **310** (cooling the second compression part **320**), when the fourth-first port **542** and the fourth-second port **544** are opened, and the fourth-third port **546** is closed, the refrigerant having passed through the first compression part **310** may be supplied to the cooling unit. In contrast, as illustrated in FIG. **3**, at the time of heating the second compression part **320** (cooling the first compression part **310**), when the fourth-first port **542** and the fourth-third port **546** are opened, and the fourth-second port **544** is closed, the cooling fluid having passed through the first compression part **310** may be supplied back to the second circulation line **420** (the cooling unit) through the fourth bypass line **460**.
(87) With the above-mentioned structure, the first and second compression parts **310** and **320** may continuously perform the process of compressing hydrogen without interruption by being alternately heated or cooled.
(88) Referring to FIG. **2**, at the time of heating the first compression part **310**, the refrigerant circulating through the first circulation line **410** may heat the first-first metal hydride compressor **312** and the first-second metal hydride compressor **314** by sequentially passing through the first-first metal hydride compressor **312** and the first-second metal hydride compressor **314**.
(89) In addition, as illustrated in FIG. **2**, the second compression part **320** may be cooled while the first compression part **310** is heated. At the time of cooling the second compression part **320**, the cooling fluid circulating through the second circulation line **420** may cool the second-first metal hydride compressor **322** and the second-second metal hydride compressor **324** by sequentially passing through the second-first metal hydride compressor **322** and the second-second metal hydride compressor **324**.
(90) In contrast, referring to FIG. **3**, at the time of heating the second compression part **320**, the refrigerant circulating through the first circulation line **410** may heat the second-first metal hydride compressor **322** and the second-second metal hydride compressor **324** by sequentially passing through the second-first metal hydride compressor **322** and the second-second metal hydride compressor **324** via the first bypass line **430**. Thereafter, the refrigerant having passed through the second compression part **320** (the second-first metal hydride compressor **322** and the second-second metal hydride compressor **324**) may be supplied back to the first circulation line **410** through the second bypass line **440**.
(91) In addition, as illustrated in FIG. **3**, the first compression part **310** may be cooled while the

second compression part **320** is heated. At the time of cooling the first compression part **310**, the cooling fluid circulating through the second circulation line **420** may cool the first-first metal hydride compressor **312** and the first-second metal hydride compressor **314** by sequentially passing through the first-first metal hydride compressor **312** and the first-second metal hydride compressor **314** via the third bypass line **450**. Thereafter, the cooling fluid having passed through the first compression part **310** (the first-first metal hydride compressor **312** and the first-second metal hydride compressor **314**) may be supplied back to the second circulation line **420** through the fourth bypass line **460**.

(92) The embodiments of the present disclosure are illustrated and described above as the first and second compression parts **310** and **320** are alternately heated or cooled. However, according to another embodiment of the present disclosure, the first and second compression parts may be simultaneously heated or simultaneously cooled. According to the embodiment of the present disclosure, the hydrogen compression system **10** may include: a first heater **412** provided in the first circulation line **410**, positioned between the first valve **510** and the first compression part **310**, and configured to heat the refrigerant; and a second heater **422** provided in the second circulation line **420**, positioned between the third valve **530** and the second compression part **320**, and configured to heat the refrigerant.

(93) The first heater **412** is configured to heat the refrigerant to be supplied to the first compression part **310** through the first circulation line **410**.

(94) Various heating means capable of heating the refrigerant to be supplied to the first compression part **310** through the first circulation line **410** may be used as the first heater **412**. The present disclosure is not restricted or limited by the type and structure of the first heater **412**. For example, a typical electric heater may be used as the first heater **412**.

(95) As described above, in the embodiment of the present disclosure, the first heater **412** may be provided in the first circulation line **410**, and the first heater **412** may additionally heat the refrigerant to be supplied to the first compression part **310** at the time of heating the first compression part **310**. Therefore, it is possible to obtain an advantageous effect of increasing the heating capacity and heating speed of the first compression part **310**.

(96) The second heater **422** is configured to heat the refrigerant to be supplied to second compression part **320** through the second circulation line **420** via the first bypass line **430**.

(97) Various heating means capable of heating the refrigerant to be supplied to the second compression part **320** through the second circulation line **420** may be used as the second heater **422**. The present disclosure is not restricted or limited by the type and structure of the second heater **422**. For example, a typical electric heater may be used as the second heater **422**.

(98) As described above, in the embodiment of the present disclosure, the second heater **422** may be provided in the second circulation line **420**, and the second heater **422** may additionally heat the refrigerant to be supplied to the second compression part **320** at the time of heating the second compression part **320**. Therefore, it is possible to obtain an advantageous effect of increasing the heating capacity and heating speed of the second compression part **320**.

(99) As described above, according to the embodiment of the present disclosure, it is possible to obtain an advantageous effect of minimizing electric power consumption and improving energy efficiency when compressing hydrogen by using the thermochemical method.

(100) In particular, according to the embodiments of the present disclosure, it is possible to operate the metal hydride compressor by using the refrigerant of the heat pump part as a heat source. Therefore, it is possible to obtain an advantageous effect of minimizing electric power consumption required for the process of compressing hydrogen and an advantageous effect of improving energy efficiency.

(101) In addition, according to the embodiments of the present disclosure, it is possible to obtain an advantageous effect of continuously extracting high-pressure hydrogen and reducing the time required for the process of compressing hydrogen.

(102) While the embodiments have been described above, the embodiments are just illustrative and not intended to limit the present disclosure. It can be appreciated by those having ordinary skill in the art that various modifications and applications, which are not described above, may be made to the present embodiment without departing from the intrinsic features of the present embodiment. For example, the respective constituent elements specifically described in the embodiments may be modified and then carried out. Further, it should be interpreted that the differences related to the modifications and applications are included in the scope of the present disclosure.

Claims

1. A hydrogen compression system comprising: a heat pump part comprising a heat pump line configured to allow a refrigerant to circulate therethrough; a hydrogen compression part configured to compress hydrogen by being repeatedly heated and cooled; a first circulation line connected to the heat pump line while passing through the hydrogen compression part and configured to allow the refrigerant introduced from the heat pump line to circulate therethrough; a second circulation line provided to pass through the hydrogen compression part and configured to allow a cooling fluid to circulate therethrough; and a cooling unit provided in the second circulation line and configured to cool the cooling fluid, wherein the hydrogen compression part is heated by the refrigerant or cooled by the cooling fluid, wherein the hydrogen compression part comprises: a first compression part configured to compress the hydrogen; and a second compression part configured to compress hydrogen independently of the first compression part, and wherein the first and second compression parts are alternately heated or cooled, wherein the hydrogen compression system further comprises: a first bypass line having a first end disposed at an upstream side of the first compression part and connected to the first circulation line, and a second end disposed at an upstream side of the second compression part and connected to the second circulation line; a second bypass line having a first end disposed at a downstream side of the second compression part and connected to the second circulation line, and a second end disposed at a downstream side of the first compression part and connected to the first circulation line; a third bypass line having a first end disposed at the upstream side of the second compression part and connected to the second circulation line, and a second end disposed at the upstream side of the first compression part and connected to the first circulation line; and a fourth bypass line having a first end disposed at the downstream side of the first compression part and connected to the first circulation line, and a second end disposed at the downstream side of the second compression part and connected to the second circulation line.
2. The hydrogen compression system of claim 1, wherein the first compression part comprises: a first-first metal hydride compressor configured to compress hydrogen; and a first-second metal hydride compressor configured to compress hydrogen independently of the first-first metal hydride compressor.
3. The hydrogen compression system of claim 2, wherein the first-first metal hydride compressor and the first-second metal hydride compressor are connected in series.
4. The hydrogen compression system of claim 1, wherein the second compression part comprises: a second-first metal hydride compressor configured to compress hydrogen; and a second-second metal hydride compressor configured to compress hydrogen independently of the second-first metal hydride compressor.
5. The hydrogen compression system of claim 4, wherein the second-first metal hydride compressor and the second-second metal hydride compressor are connected in series.
6. The hydrogen compression system of claim 1, comprising: a first valve provided in the first circulation line and configured to selectively switch a flow path of the refrigerant introduced from the heat pump line to the first bypass line; a second valve provided in the second circulation line and configured to selectively switch a flow path of the refrigerant having passed through the

second compression part to the second bypass line; a third valve provided in the second circulation line and configured selectively switch a flow path of the cooling fluid having passed through the cooling unit to the third bypass line; and a fourth valve provided in the first circulation line and configured to selectively switch a flow path of the cooling fluid having passed through the first compression part to the fourth bypass line.

7. The hydrogen compression system of claim 6, comprising: a first heater provided in the first circulation line, positioned between the first valve and the first compression part, and configured to heat the refrigerant; and a second heater provided in the second circulation line, positioned between the third valve and the second compression part, and configured to heat the refrigerant.

8. The hydrogen compression system of claim 1, wherein the heat pump part comprises: a compressor provided in the heat pump line and configured to compress the refrigerant; a condenser provided in the heat pump line and configured to condense the refrigerant; an expansion valve provided in the heat pump line and configured to decompress the refrigerant; and an evaporator provided in the heat pump line and configured to vaporize the refrigerant, and wherein the first circulation line is connected to the condenser or the evaporator.