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(54) **COMPRESSOR ASSEMBLY SYSTEM AND LOW-TEMPERATURE GAS COMPRESSION METHOD**

(57) A compressor assembly system and a low-temperature gas compression method. The compressor assembly system comprises a first compressor assembly (101) and a second compressor assembly (102) connected in sequence, a driving device (50), and a transmission device (60); the transmission device (60) has a first input shaft extension end (64) and a plurality of second output shaft extension ends (61); the driving device (50) provides power to the transmission device (60) by means of the first input shaft extension end (64); the transmission device (60) transmits power to the first compressor assembly (101) and the second compressor assembly (102) by means of the second output shaft extension ends (61). **In** the working process, a plurality of compressor assemblies share one driving device by means of one transmission device, so that the device amount can be reduced, the space requirement of the devices is reduced, and the marine space requirement is further met.

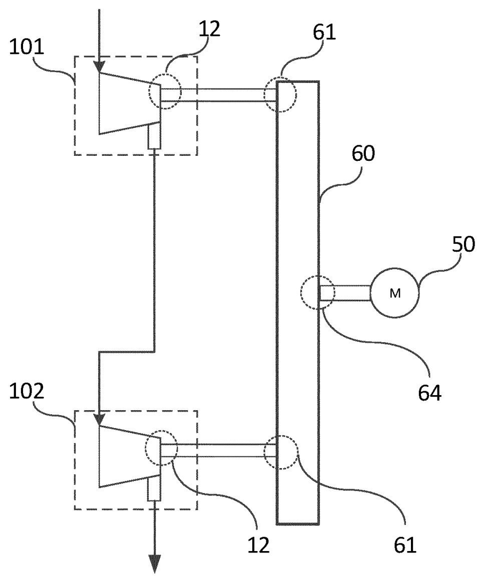

FIG. 1

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Chinese Patent Application No. 202310592731.9 filed on May. 24, 2023 and entitled "A COMPRESSOR ASSEMBLY SYSTEM AND LOW-TEMPERATURE GAS COMPRESSION METHOD", the disclosures of which are incorporated by reference herein in their entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to the technical field of compressor, and in particular, relates to a compressor assembly system and low-temperature gas compression method.

BACKGROUND

[0003] At present, marine low-temperature gas compressor can be divided into gas compressors and return gas compressors according to their use, wherein, gas compressor is mainly configured to pressurize Boil-Off Gas (BOG) generated in LNG (Liquefied Natural Gas) storage device and deliver to gas consumers on board. With the technological upgrade of ship liquid cargo containment system, the evaporation volume of cargo tank has been greatly reduced, screw compressor has gradually replaced other types of compressor structures and become the mainstream structure of gas compressor. However, the traditional compressor assembly system requires a large space and cannot meet the requirements for the marine space.

TECHNICAL SOLUTIONS

[0004] Based on this, it is necessary to provide a compressor assembly system and low-temperature gas compression method to improve the aforementioned defects, addressing the technical problems of the large space requirement of traditional compressor assembly system in existing technology.

[0005] In a first aspect, a compressor assembly system, comprises:

a first compressor assembly and a second compressor assembly connected in sequence, the first compressor assembly and the second compressor assembly are provided with a power input end respectively;
a driving device;
a transmission device, the transmission device is provided with a first input shaft extension end and a plurality of second output shaft extension ends, the first input shaft extension end is connected with the output end of the driving device, the second output shaft extension end is connected with the power input end in a one-to-one correspondence.

[0006] Optionally, the second output shaft extension end and the power input end are connected in one-to-one correspondence through a first coupling;
the first input shaft extension end and the output end of the driving device are connected through a second coupling.

[0007] Optionally, the first compressor assembly, the second compressor assembly and the transmission device are provided with a lubricating oil receiving end respectively;

the compressor assembly system further comprises:
a lubricating device, the lubricating device is provided with a plurality of lubricating output ends, the lubricating output end is connected with the lubricating oil receiving end in a one-to-one correspondence.

[0008] Optionally, the lubricating device is provided with an oil mist separator, the oil mist separator is configured to conduct oil and mist separation to the lubricating oil.

[0009] Optionally, the compressor assembly system further comprises:

a preheater, the preheater is provided with a first cold end inlet, a first cold end outlet, a first hot end inlet and a first hot end outlet, the first cold end inlet is configured to input low-temperature gas to be compressed, the first cold end outlet is connected with the inlet of the first compressor assembly, the first hot end outlet is connected with the outlet of the first compressor assembly;
an aftercooler, the aftercooler is provided with a second hot end inlet and a second hot end outlet, the second hot end inlet is connected with the first hot end outlet, the second hot end outlet is configured to output the cooled compressed low-temperature gas.

[0010] Optionally, the compressor assembly system further comprises:
an interstage cooler, the interstage cooler is connected between the first compressor assembly and the second compressor assembly, the interstage cooler is configured to cool the gas output from the first compressor assembly through a cooling medium, and output the cooled gas to the second compressor assembly.

[0011] Optionally, the interstage cooler is provided with a third cold end inlet, a third cold end outlet, a third hot end inlet and a third hot end outlet;
the third hot end inlet is connected with the outlet of the first compressor assembly, the third hot end outlet is connected with the inlet of the second compressor assembly, the third cold end inlet is configured to input the cooling medium, the third cold end outlet is configured to output the heat-exchanged cooling medium.

[0012] Optionally, the aftercooler is further provided with a second cold end inlet and a second cold end outlet;
the second cold end inlet is connected with the third cold end outlet, the second cold end outlet is configured to output the cooling medium heat-exchanged again.

[0013] Optionally, the outlet of the first compressor assembly and the outlet of the second compressor assembly are provided with a silencer respectively.

[0014] Optionally, the first compressor assembly and the second compressor assembly are provided with a sealing gas receiving end respectively;

the compressor assembly system further comprises:
a sealing device, the sealing device is provided with a sealing gas input port and a plurality of sealing gas output ports, the sealing gas input port is configured to input the sealing gas, the sealing gas output port is connected with the sealing gas receiving end in a one-to-one correspondence.

[0015] Optionally, the first compressor assembly comprises a first screw compressor, the second compressor assembly comprises a second screw compressor.

[0016] In a second aspect, a low-temperature gas compression method of a compressor assembly system is further disclosed, comprises:

transmitting power, by the driving device, to the transmission device through the first input shaft extension end of the transmission device;
transmitting power, by the transmission device, to the first compressor assembly and the second compressor assembly connected in sequence through each of the second output shaft extension ends;
compressing, by the first compressor assembly driven by power, the low-temperature gas to be compressed and output intermediate compressed gas to the second compressor assembly; and
compressing, by the second compressor assembly driven by power, the intermediate compressed gas and output the compressed low-temperature gas.

BENEFICIAL EFFECT

[0017] **The** compressor assembly system of the embodiment of the present application comprises: a first compressor assembly and a second compressor assembly connected in sequence, a driving device and a transmission device, the transmission device is provided with a first input shaft extension end and a plurality of second output shaft extension ends, the driving device transmits power to the transmission device through the first input shaft extension end, the transmission device transmits power to the first compressor assembly and the second compressor assembly through each of the second output shaft extension ends, a plurality of compressor assemblies share one driving device by means of one transmission device in the whole process, so that the device amount can be reduced, the space requirement of the devices is reduced, and the requirement for marine space is further met.

[0018] The low-temperature gas compression method of the compressor assembly system of the embodiment of the present application comprises: the driving device transmits power to the transmission device through the first input shaft extension end of the transmission device, the transmission device transmits power to the first compressor assembly and the second compressor assembly connected in sequence through each of the second output shaft extension ends, the first compressor assembly and the second compressor assembly compress the low-temperature gas to be compressed under the driving of corresponding power. It can be understood that the low-temperature gas compression method can possess all the technical features and beneficial effects of the above-mentioned compressor assembly system, in particular, the low-temperature gas compression method can transmit the power of the same driving device through the same transmission device, the device amount can be reduced, so that the space requirement of the devices is reduced, and the marine space requirement is further met.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

FIG. 1 is an overall structural schematic diagram of the compressor assembly system of the embodiment of the present application;
FIG. 2 is a specific structural schematic diagram of the compressor assembly system of the embodiment of the present application;
FIG. 3 is an axial structural schematic diagram of the compressor assembly system of the embodiment of the present application;
FIG. 4 is a top structural schematic diagram of the compressor assembly system in FIG. 3;

[0020] Reference signs: 101-first compressor assembly; 102-second compressor assembly; 11-silencer; 12-power input end; 13-lubricating oil receiving end; 14-sealing gas receiving end; 20-preheater; 21-first cold end inlet; 22-first cold end outlet; 23-first hot end inlet; 24-first hot end outlet; 30-aftercooler; 31-second hot end inlet; 32-second hot end outlet; 33-second cold end inlet; 34-second cold end outlet; 40-interstage cooler; 41-third cold end inlet; 42-third cold end outlet; 43-third hot end inlet; 44-third hot end outlet; 50-driving device; 60-transmission device; 61-second output shaft extension end; 62-first coupling; 63-second coupling; 64-first input shaft extension end; 70-lubricating device; 71-oil mist separator; 72-lubricating output end; 80-sealing device; 81-sealing gas input port; 82-sealing gas output port.

DETAILED DESCRIPTION

[0021] The technical solutions in the embodiments of the present application will be clearly and completely described below with reference to the accompanying drawings in the embodiments of the present application. The described embodiments are only some of the embodiments of the present application, but not all of the embodiments. Based on the embodiments in this application, all other embodiments obtained by those skilled in the art without making creative efforts fall within the scope of protection of this application.

[0022] At present, marine low-temperature gas compressor can be divided into reciprocating compressor, screw compressor and centrifugal compressor according to different compressor structures. Wherein, the reciprocating compressor has a long history of development and mature technology, almost all early low-temperature BOG compressors adopted reciprocating compressors, however, the reciprocating compressor has shortcomings such as the period of inspection and maintenance is short and the amount of wearing part is large, which causes a huge burden to daily operation and maintenance, especially for LNG ships that have been isolated from the outside world for a long time, inspection and maintenance work is particularly inconvenient, and the failure of the BOG compressor also adversely affect the safety of the LNG ship. The centrifugal compressor supercharges the gas mainly through the rotation of the impeller, the centrifugal compressor is mainly suitable for the application with medium and large flow rate and low pressure ratio, addressing the requirement of gas compression use of the LNG ship, in case where the centrifugal compressor is adopted, 4-6 stage compression structure is required, which will greatly increase the difficulty of unit control operation. At the same time, with the technological upgrade of ship liquid cargo containment system, the evaporation volume of cargo tank has been greatly reduced, screw compressor has gradually replaced other types of compressor structures and become the mainstream structure of gas compressor.

[0023] At present, commonly used marine low-temperature gases mainly comprise natural gas, a mixture of natural gas and nitrogen, ammonia, and other low-temperature gases in offshore equipment and processes, in the multi-stage screw compressor assembly used to compress these low-temperature gases, the screw compressor assembly at each stage is usually provided with independent gear transmission device and motor, when applied on a ship, this structure may not meet space requirements or may not be optimal.

[0024] In view of this, the embodiment of the present application provides a compressor assembly system to solve at least part of the aforementioned technical problems.

[0025] Please refer to FIG. 1, FIG. 1 illustrates the overall structure of the compressor assembly system of the embodiment of the present application. In the embodiment of the present application, the compressor assembly system comprises a first compressor assembly 101 and a second compressor assembly 102 connected in sequence, and a driving device 50 and a transmission device 60. Wherein, the first compressor assembly 101 and the second compressor assembly 102 are provided with a power input end 12 respectively. The transmission device 60 is provided with a first input shaft extension end 64 and a plurality of second output shaft extension ends 61, the first input shaft extension end 64 is connected with the output end of the driving device 50, the second output shaft extension end 61 is connected with the power input end 12 in a one-to-one correspondence.

[0026] In some embodiments, the second output shaft extension end 61 and the power input end 12 are connected in one-to-one correspondence through a first coupling 62, the first input shaft extension end 64 and the output end of the driving device 50 are connected through a second coupling 63. The driving device 50 can be a motor. Wherein, the first input shaft extension end 64 is a low-speed input shaft extension end, the rotation speed of the first input shaft extension end 64 can be 1500 rpm or 1800 rpm. The second output shaft extension end 61 is a high-speed output shaft extension end, the rotation speed of the second output shaft extension end 61 is 3000 rpm to 10000 rpm. In some embodiments, the rotation speed of the second output shaft extension end 61 can be any one of 3000 rpm, 3500 rpm, 4000 rpm, 4500 rpm, 5000 rpm, 5500 rpm, 6000 rpm, 6500 rpm, 7000 rpm, 7500 rpm, 8000 rpm, 8500 rpm, 9000 rpm, 9500 rpm, 10000 rpm, or ranges between any two of them.

[0027] Optionally, the transmission device 60 is configured to adopt independent gear transmission device, the plurality of second output shaft extension ends 61 of the gear transmission device are respectively connected with the male rotor extension end of the compressors at each stage through the first coupling 62, achieving the driving to compressors at each stage though such shaft connection method. In this way, adopting the structural design of a plurality of compressors share one motor driving by means of one gear transmission device, the space requirement of the unit can be reduced by reducing the amount of the device, thereby meeting the space requirements of the ship and better meeting the requirements of compact structure of the space when the marine screw low-temperature compressor is applied on the ship.

[0028] In some embodiments, the first compressor assembly 101 can comprise a first screw compressor, the second compressor assembly 102 can comprise a second screw compressor. Furthermore, a dry oil-free screw compressor can be adopted, therefore, adopting a dry oil-free screw compressor, an oil separation device cannot be set additionally, the structure is simpler and more compact. For example, the single-stage pressure ratios of both the first compressor assembly 101 and the second compressor assembly 102 range from 1.5 to 3.5. ins some embodiments, the single-stage pressure ratio range of the first compressor assembly 101 and the second compressor assembly 102 can be any one of 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, or ranges between any two of them. The pressure ratio range of the first compressor assembly 101 and the second compressor assembly 102 can be same of different, for example, 1 bar of gas can be compressed to 7 bar through two stage compression of the first compressor assembly 101 and the second compressor assembly 102.

[0029] In some embodiments, at least one stage of compressor assembly is further configured to be disposed between the outlet of the first compressor assembly 101 and the inlet of the second compressor assembly 102, to achieve three-stage or higher compression of the low-temperature gas to be compressed.

[0030] Please refer to FIG. 2, FIG. 3 and FIG. 4 together, FIG. 2 illustrates a specific structure of the compressor assembly system of the embodiment of the present application, FIG. 3 illustrates an axial structure of the compressor assembly system of the embodiment of the present application, FIG. 4 illustrates a top structure of the compressor assembly system in FIG. 3. In some embodiments of the present application, the first compressor assembly 101, the second compressor assembly and the transmission device 60 can be provided with a lubricating oil receiving end 13 respectively. The compressor assembly system can further comprise a lubricating device 70. The lubricating device 70 is provided with a plurality of lubricating output ends 72, the lubricating output end 72 is connected with the lubricating oil receiving end 13 in a one-to-one correspondence. In some embodiments, the housings of the first compressor assembly 101 and the second compressor assembly 102 are both provided with a heat exchange channel, the heat exchange channel is connected with the lubricating device 70 to cool the housing through the lubricating oil. In this way, the lubricating device 70 is configured to supply the compressor with lubricating oil which provides the function of lubricating and cooling to the bearings and gears, thereby fully utilizing the stepped oil temperature design within the system, preventing uneven temperature distribution on the housing of the compressor housing without the need to separately introduce an external cooling medium, reducing the external interface of the unit and facilitating installation and maintenance.

[0031] In some embodiments, the lubricating device 70 can be provided with an oil mist separator 71, the oil mist separator 71 is configured to conduct oil mist separation on the lubricating oil. For example, the oil mist separator 71 can be electric or pneumatic. In this way, by setting up unique jet oil mist separator 71, smooth oil return can be achieved and lubricating oil leakage can be avoided, and oil vapor will not be emitted to affect the environment, thus ensuring the reliability of system operation.

[0032] In some embodiments, the first compressor assembly 101 and the second compressor assembly 102 can be provided with a sealing gas receiving end 14 respectively. The compressor assembly system can further comprise a sealing device 80, the sealing device 80 is provided with a sealing gas input port 81 and a plurality of sealing gas output ports 82, the sealing gas input port 81 is configured to input sealing gas, for example, the sealing gas input port 81 can be connected with a sealing gas interface Sin, the sealing gas can be an inert gas such as nitrogen. In some embodiments, the pressure range of the sealing gas is 4bar to 10bar. The flow rate range of the sealing gas is less than 20Nm^3/h. In some embodiments, the pressure range of the sealing gas is any one of 4bar, 4.5bar, 5bar, 5.5bar, 6bar, 6.5bar, 7bar, 7.5bar, 8bar, 8.5bar, 9bar, 9.5bar, 10bar, or ranges between any two of them. The sealing gas output port 82 is connected with the sealing gas receiving end 14 in a one-to-one correspondence. In this way, the first compressor assembly 101 and the second compressor assembly 102 can utilize the sealing gas to achieve sealing through special structural design of sealing chamber, thus ensuring that a better sealing effect can be achieved under the condition of the pressure and/or the flow of the sealing gas is limited in a marine environment. The sealing device 80 can supply the first compressor assembly

101 and the second compressor assembly 102 with sealing gas to achieve shaft sealing of the compressor, by monitoring and controlling the flow of the sealing gas, it can also ensure that the non-contact sealing structure adopted in the compressor at each stage can operate safely and reliably, such non-contact sealing structure can better prevent flammable and explosive compressed media from leaking out of the compression chambers of compressors at each stage and causing safety hazards, thereby ensuring the safety operation of the unit.

[0033] In some embodiments, the compressor assembly system further comprises a preheater 20 and aftercooler 30.

[0034] In the embodiment of the present application, the heat exchange between the preheater 20 and the aftercooler 30 follows the following formula (1):

$$\begin{cases} Q_1 = c_1 \times \Delta t \times m_1 \\ Q_2 = c_2 \times \Delta t \times m_2 \\ Q_1 = Q_2 \end{cases} \qquad \text{formula (1)}$$

[0035] In formula (1), Q_1 is the heat absorbed by the cold end, c_1 is the heat capacity of the medium passing through the cold end, Δt is the temperature difference between the medium passing through the cold end and the medium passing through the hot end, m_1 is the flow of the medium passing through the cold end, Q_2 is the heat released by the hot end, c_2 is the heat capacity of the medium passing through the hot end, Δt is the temperature difference between the medium passing through the cold end and the medium passing through the hot end, m_2 is the flow of the medium passing through the hot end.

[0036] Specifically, the preheater 20 is provided with a first cold end inlet 21, a first cold end outlet 22, a first hot end inlet 23 and a first hot end outlet 24. The first cold end inlet 21 is configured to input low-temperature gas to be compressed, for example, the first cold end inlet 21 can be connected with the low-temperature gas inlet BOGin. For example, the low-temperature gas to be compressed can comprise natural gas, a mixture of natural gas and nitrogen, ammonia, and other flammable and explosive low-temperature gases in offshore equipment and processes, the temperature range of the low-temperature gas to be compressed is -140°C to +35°C. In some embodiments, the temperature of the low-temperature gas to be compressed is any one of -140°C, -130°C, -120°C, -110°C, -100°C, -90°C, -80°C, -70°C, -60°C, -50°C, -40°C, -30°C, -20°C, -10°C, 0°C, +10°C, +20°C, +30°C, +31°C, +32°C, +33°C, +34°C, +35°C, or ranges between any two of them. The pressure range of the low-temperature gas to be compressed can be normal pressure, for example: 1bar, the flow range of the low-temperature gas to be compressed is 500kg/h to 4000kg/h. In some embodiments, the flow of the low-temperature gas to be compressed is any one of 500kg/h, 800kg/h, 1000kg/h, 1200kg/h, 1500kg/h, 1800kg/h, 2000kg/h, 2200kg/h, 2500kg/h, 2800kg/h, 3000kg/h, 3200kg/h, 3500kg/h, 3800kg/h, 4000kg/h, or ranges between any two of them. The gas temperature output from the first hot end outlet 24 is greater than or equal to 90°C. In the embodiment of the present application, the preheater 20 exchanges the heat with the cold medium through the hot medium, the cold medium passes through the connecting pipe formed between the first cold end inlet 21 and the first cold end outlet 22, the hot medium passes the connecting pipe formed between the first hot end inlet 23 and the first hot end outlet 24, thereby achieving the function of heating the cold medium and cooling the hot medium at the same time.

[0037] Specifically, the aftercooler 30 is provided with a second hot end inlet 31 and a second hot end outlet 32, the second hot end inlet 31 is connected with the first hot end outlet 24, the second hot end inlet 31 is configured to input the compressed low-temperature gas which has undergone initial cooling, the second hot end outlet 32 is configured to output cooled compressed low-temperature gas, for example: the second hot end outlet 32 is configured to be connected with the low-temperature gas BOGout, the temperature of the compressed low-temperature gas, which has undergone initial cooling and is input through the second hot end inlet 31, is greater than or equal to 90°C, the temperature of the final low-temperature gas output through the second hot end outlet 32 is less than or equal to 50°C. In the embodiment of the present application, the aftercooler 30 is further provided with a second cold end inlet 33 and a second cold end outlet 34, the second cold end inlet 33 is configured to input cooling medium, for example: the second cold end inlet 33 is configured to be connected with the cooling medium inlet Cin, the second cold end outlet 34 is configured to output the heat-exchanged cooling medium, for example: the second cold end outlet 34 is configured to be connected with the cooling medium outlet Cout, the cooling medium can be cooling water, cooling air, or other types of cooling medium. Specifically, the heat-exchange temperature can be controlled by controlling the flow range of the cooling medium. In this way, the aftercooler 30 exchanges the heat with the compressed low-temperature gas which has undergone initial cooling through the cooling medium, the compressed low-temperature gas which has undergone initial cooling passes through the connecting pipe formed between the second hot end inlet 31 and the second hot end outlet 32, the cooling medium passes the connecting pipe formed between the second cold end inlet 33 and the second cold end outlet 34, thereby achieving the function of cooling the compressed low-temperature gas which has undergone initial cooling again.

[0038] Specifically, the first compressor assembly 101 is configured to perform first stage compression on the heat-exchanged low-temperature gas to be compressed and output intermediate compressed gas. The inlet of the second compressor assembly 101 is connected with the outlet of the first compressor assembly 101, the second compressor assembly 102 is configured to perform second stage compression on the intermediate compressed gas and output compressed low-temperature gas. The compressed low-temperature gas will be finally output after initial cooling by the preheater 20 and secondary cooling by the aftercooler 30. Therefore, the independent design of the multi-stage compressor unit makes the installation and maintenance of the unit in the marine environment more convenient.

[0039] By setting up the aforementioned preheater and aftercooler, using in conjunction with an oil-free screw compressor, it is possible to achieve to maximally adapt to the compression working conditions of low flow, large temperature difference, and high pressure ratio for marine low-temperature gases, when both the inlet temperature and outlet temperature of the compressor meet the structural design requirement of the screw compressor.

[0040] It can be understood that the compressor assembly system preheats the low-temperature gas by disposing the preheater 20 at the inlet of the first compressor assembly 101, so that the gas temperature at the inlet of the first compressor assembly 101 can meet the structural design requirement of the first compressor assembly 101, and the preheater 20 utilizes the temperature of the compressed gas output from the second compressor assembly 102 to preheat the low-temperature gas, at the same time, the low-temperature can further cool the compressed gas output from the second compressor assembly 102 and then input the cooled compressed gas to the aftercooler 30 to perform secondary cooling, the whole process can fully recover the compression heat of the compression process, which can greatly reduce the energy consumption of the compression process and has good energy saving performance.

[0041] In some embodiments, the compressor assembly system further comprises interstage cooler 40. Wherein, the interstage cooler 40 is connected between the first compressor assembly 101 and the second compressor assembly 102, the interstage cooler 40 is configured to cool the gas output from the first compressor assembly 101 through a cooling medium, and output the cooled gas to the second compressor assembly 102, the cooling medium can be cooling water, cooling air, or other types of cooling medium. Therefore, the inlet temperature and outlet temperature of the compressors at each stages can meet the structural design of the screw compressor, which is more favorable for the compression of low-temperature gas.

[0042] In the embodiment of the present application, the heat-exchange of the interstage cooler 40 also follows the aforementioned formula (1), the formula (1) is not described here again.

[0043] Specifically, the interstage cooler 40 is provided with a third cold end inlet 41, a third cold end outlet 42, a third hot end inlet 43 and a third hot end outlet 44. Wherein, the third hot end inlet 43 is connected with the outlet of the first compressor assembly 101, for example: the gas temperature input from the third hot end inlet 43 is less than or equal to 200°C. The third hot end outlet 44 is connected with the inlet of the second compressor assembly 102, for example: the range of the gas temperature output from the third hot end outlet 44 is 10°C to 45°C. In some embodiments, the gas temperature output from the third hot end outlet 44 is any one of 10°C, 12°C, 14°C, 16°C, 18°C, 20°C, 22°C, 24°C, 26°C, 28°C, 30°C, 32°C, 34°C, 36°C, 38°C, 40°C, 42°C, 43°C, 44°C, 45°C, or ranges between any two of them. The third cold end inlet 41 is configured to input cooling medium, for example: the tempertature range of the cooling medium is 20°C to 30°C. In some embodiments, the temperature of the cooling medium is any one of 20°C, 21°C, 22°C, 23°C, 24°C, 25°C, 26°C, 27°C, 28°C, 29°C, 30°C, or ranges between any two of them. The flow range of the cooling medium is 4.5t/h to 45t/h, specifically, the heat-exchange temperature can be controlled by controlling the flow range of the cooling medium. In some embodiments, the flow of the cooling medium is any one of 4.5t/h, 4.6t/h, 4.7t/h, 4.8t/h, 4.9t/h, 5t/h, 7t/h, 10t/h, 12t/h, 15t/h, 18t/h, 20t/h, 22t/h, 25t/h, 27t/h, 30t/h, 32t/h, 35t/h, 37t/h, 40t/h, 42t/h, 45t/h, or ranges between any two of them. The third cold end outlet 42 is configured to output the cooling medium after heat exchange, for example: the temperature of the cooling medium after heat exchange is 30°C to 40°C. In some embodiments, the temperature of the cooling medium after heat exchange is any one of 30°C, 31°C, 232°C, 33°C, 34°C, 35°C, 36°C, 37°C, 38°C, 39°C, 40°C, or ranges between any two of them. That is to say, the interstage cooler 40 in the embodiment of the present application cools the intermediate compressed gas through the cooling medium, the intermediate compressed gas passes through the connecting pipe formed between the third hot end inlet 43 and the third hot end outlet 44, to achieve the function of cooling the gas that has been heated after compression.

[0044] In some embodiments, the second cold end inlet 33 is configured to be connected with the third cold end outlet 42, so that the second cold end outlet 34 can output the cooling medium that has been heat-exchanged again. In this way, the aftercooler 30 can utilize the residual cooling effect of the cooling medium in the interstage cooler 40 to perform secondary cooling on the compressed low-temperature gas that has been initially cooled, thereby saving the amount of cooling medium and further reducing system energy consumption.

[0045] By setting up the aforementioned interstage cooler 40, the heat-exchange system composed of the interstage cooler 40, the preheater 20 and the aftercooler 30 is used in conjunction with the multi-stage dry oil-free screw compressor unit, it is possible to achieve to maximally adapt to the compression working conditions of low flow, large temperature difference, and high pressure ratio for marine low-temperature gases, when both the inlet temperature and outlet temperature of the compressor meet the structural design requirement of the screw compressor. At the same time, through the heat-exchange between the preheater 20, the aftercooler 30 and the interstage cooler 40, the heat-exchange system can reduce the amount of the external cooling medium, and at the same time, the heat-exchange system can fully recover the compression heat of the compression process and improve the energy efficiency of the unit.

[0046] In some embodiments, the outlet of the first compressor assembly 101 and the outlet of the second compressor assembly 102 can be provided with a silencer 11 respectively. In this way, the noise generated during compression can be better reduced and meet the noise requirements in marine working conditions.

[0047] By setting up the aforementioned devices, the compressor assembly system of the embodiment of the present application can better adapt to the application conditions where the working condition of low-temperature gas has large fluctuation, small volume and high pressure ratio, and the medium of the compressor is flammable and explosive, at the same time, it can meet different offshore application scenarios with fewer compressor stages and more reliable operating performance, while also taking into account energy saving requirements.

[0048] Correspondingly, the embodiment of the present application further provides a low-temperature gas compression method of the aforementioned compressor assembly system, the method comprises the following steps:

[0049] Transmitting power, by the driving device 50, to the transmission device 60 through the first input shaft extension end 64 of the transmission device 60.

[0050] Transmitting power, by the transmission device 60, to the first compressor assembly 101 and the second compressor assembly 102 connected in sequence through each of the second output shaft extension ends 61.

[0051] Compressing, by the first compressor assembly 101 driven by power, the low-temperature gas to be compressed and output intermediate compressed gas to the second compressor assembly 102.

[0052] Compressing, by the second compressor assembly 102 driven by power, the intermediate compressed gas and output the compressed low-temperature gas.

[0053] In the aforementioned embodiments, each embodiment has its own emphasis in description, for parts that are not described in detail in a certain embodiment, please refer to the relevant descriptions of other embodiments.

[0054] The compressor assembly system and low-temperature gas compression method provided by the embodiments of the present application are introduced in detail above, and specific examples are used to illustrate the principles and implementation methods of the present application, the description of the above embodiments is only intended to aid in understanding the technical solutions and core ideas of this application. Those skilled in the art should understand that they can still make modifications to the technical solutions described in the aforementioned embodiments or make equivalent replacements for some of the technical features. Such modifications or replacements do not cause the essence of the corresponding technical solutions to depart from the scope of the technical solutions of the embodiments of this application.

Claims

1. A compressor assembly system, wherein, the compressor assembly system comprises:

    a first compressor assembly and a second compressor assembly connected in sequence, the first compressor assembly and the second compressor assembly are provided with a power input end respectively;
    a driving device;
    a transmission device, the transmission device is provided with a first input shaft extension end and a plurality of second output shaft extension ends, the first input shaft extension end is connected with the output end of the driving device, the second output shaft extension end is connected with the power input end in a one-to-one correspondence.

2. The compressor assembly system according to claim 1, wherein the second output shaft extension end and the power input end are connected in one-to-one correspondence through a first coupling;
the first input shaft extension end and the output end of the driving device are connected through a second coupling.

3. The compressor assembly system according to claim 2, wherein the first compressor assembly, the second compressor assembly and the transmission device are provided with a lubricating oil receiving end respectively;
the compressor assembly system further comprises:
a lubricating device, the lubricating device is provided with a plurality of lubricating output ends, the lubricating output end is connected with the lubricating oil receiving end in a one-to-one correspondence.

4. The compressor assembly system according to claim 3, wherein the lubricating device is provided with an oil mist

separator, the oil mist separator is configured to conduct oil and mist separation to the lubricating oil.

5. The compressor assembly system according to claim 1, wherein the compressor assembly system further comprises:

a preheater, the preheater is provided with a first cold end inlet, a first cold end outlet, a first hot end inlet and a first hot end outlet, the first cold end inlet is configured to input low-temperature gas to be compressed, the first cold end outlet is connected with the inlet of the first compressor assembly, the first hot end outlet is connected with the outlet of the first compressor assembly;
an aftercooler, the aftercooler is provided with a second hot end inlet and a second hot end outlet, the second hot end inlet is connected with the first hot end outlet, the second hot end outlet is configured to output the cooled compressed low-temperature gas.

6. The compressor assembly system according to claim 5, wherein further comprises:
an interstage cooler, the interstage cooler is connected between the first compressor assembly and the second compressor assembly, the interstage cooler is configured to cool the gas output from the first compressor assembly through a cooling medium, and output the cooled gas to the second compressor assembly.

7. The compressor assembly system according to claim 6, wherein the interstage cooler is provided with a third cold end inlet, a third cold end outlet, a third hot end inlet and a third hot end outlet;
the third hot end inlet is connected with the outlet of the first compressor assembly, the third hot end outlet is connected with the inlet of the second compressor assembly, the third cold end inlet is configured to input the cooling medium, the third cold end outlet is configured to output the heat-exchanged cooling medium.

8. The compressor assembly system according to claim 7, wherein the aftercooler is further provided with a second cold end inlet and a second cold end outlet;
the second cold end inlet is connected with the third cold end outlet, the second cold end outlet is configured to output the cooling medium heat-exchanged again.

9. The compressor assembly system according to claim 5, wherein the temperature range of the low-temperature gas to be compressed is -140°C to +35°C.

10. The compressor assembly system according to claim 1, wherein the outlet of the first compressor assembly and the outlet of the second compressor assembly are provided with a silencer respectively.

11. The compressor assembly system according to claim 1, wherein the first compressor assembly and the second compressor assembly are provided with a sealing gas receiving end respectively;
the compressor assembly system further comprises:
a sealing device, the sealing device is provided with a sealing gas input port and a plurality of sealing gas output ports, the sealing gas input port is configured to input the sealing gas, the sealing gas output port is connected with the sealing gas receiving end in a one-to-one correspondence.

12. The compressor assembly system according to claim 11, wherein the pressure range of the sealing gas is 4bar to 10bar, the flow rate range of the sealing gas is less than $20Nm^3/h$.

13. The compressor assembly system according to claim 11, wherein the first compressor assembly comprises a first screw compressor, the second compressor assembly comprises a second screw compressor.

14. The compressor assembly system according to claim 11, wherein the single-stage pressure ratios of both the first compressor assembly and the second compressor assembly range from 1.5 to 3.5.

15. A low-temperature gas compression method, wherein the compressor assembly system according to any one of claims 1 to 14 is applied for compression; the method comprises the following steps:

transmitting power, by the driving device, to the transmission device through the first input shaft extension end of the transmission device;
transmitting power, by the transmission device, to the first compressor assembly and the second compressor assembly connected in sequence through each of the second output shaft extension ends;
compressing, by the first compressor assembly driven by power, the low-temperature gas to be compressed and

output intermediate compressed gas to the second compressor assembly; and
compressing, by the second compressor assembly driven by power, the intermediate compressed gas and output the compressed low-temperature gas.

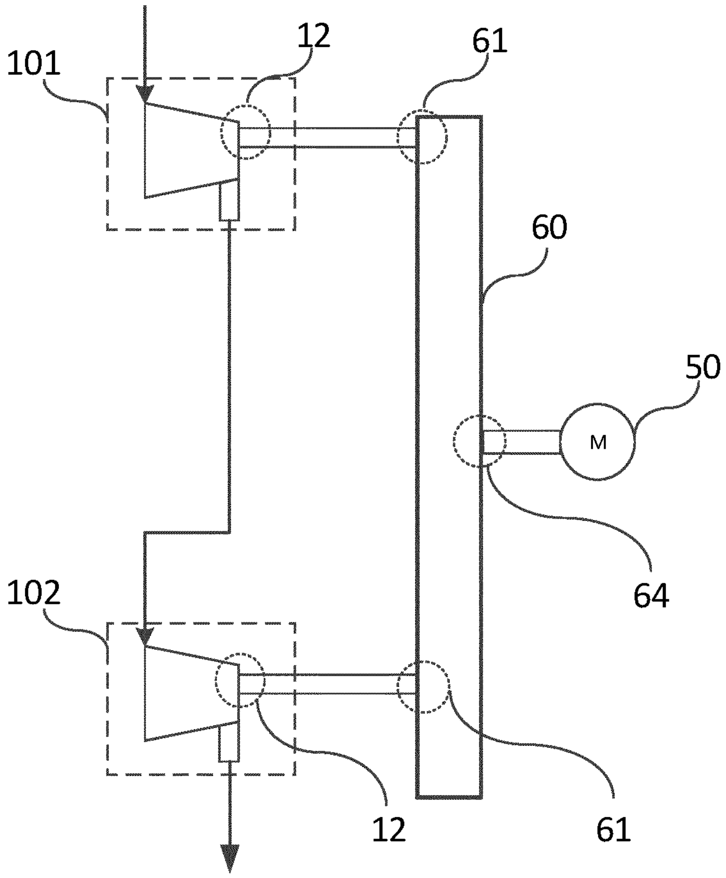
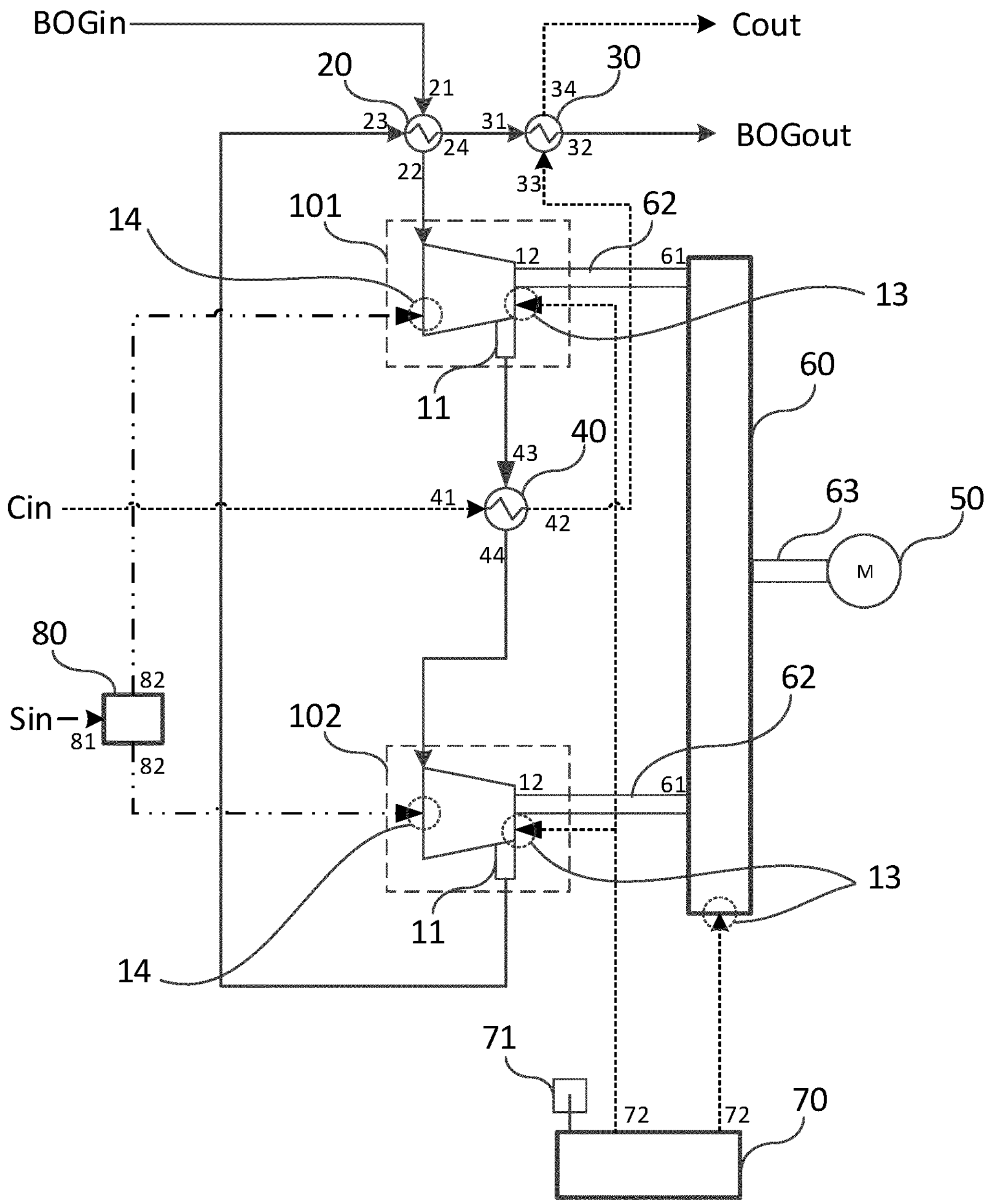


FIG. 1


BOGin
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BOGout
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FIG. 2

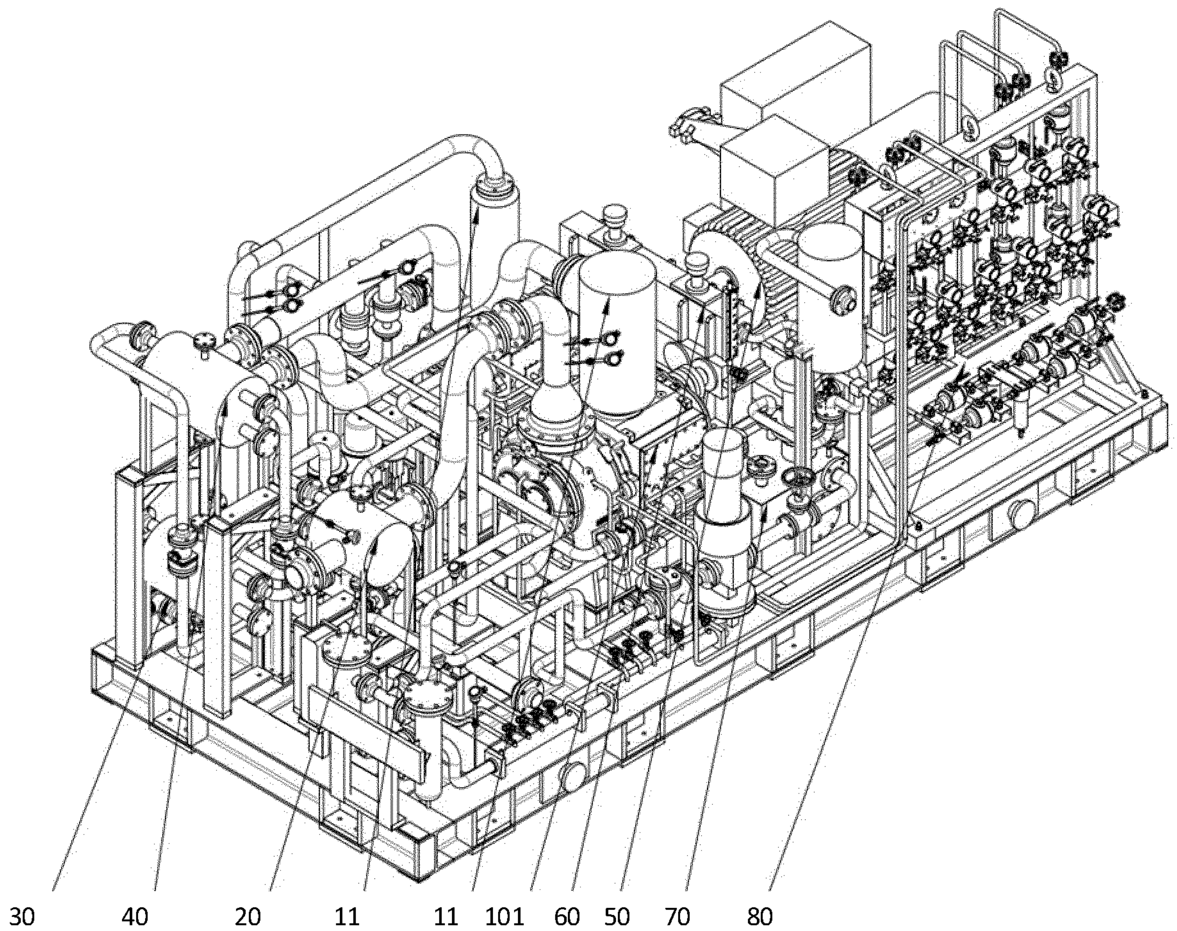

FIG. 3

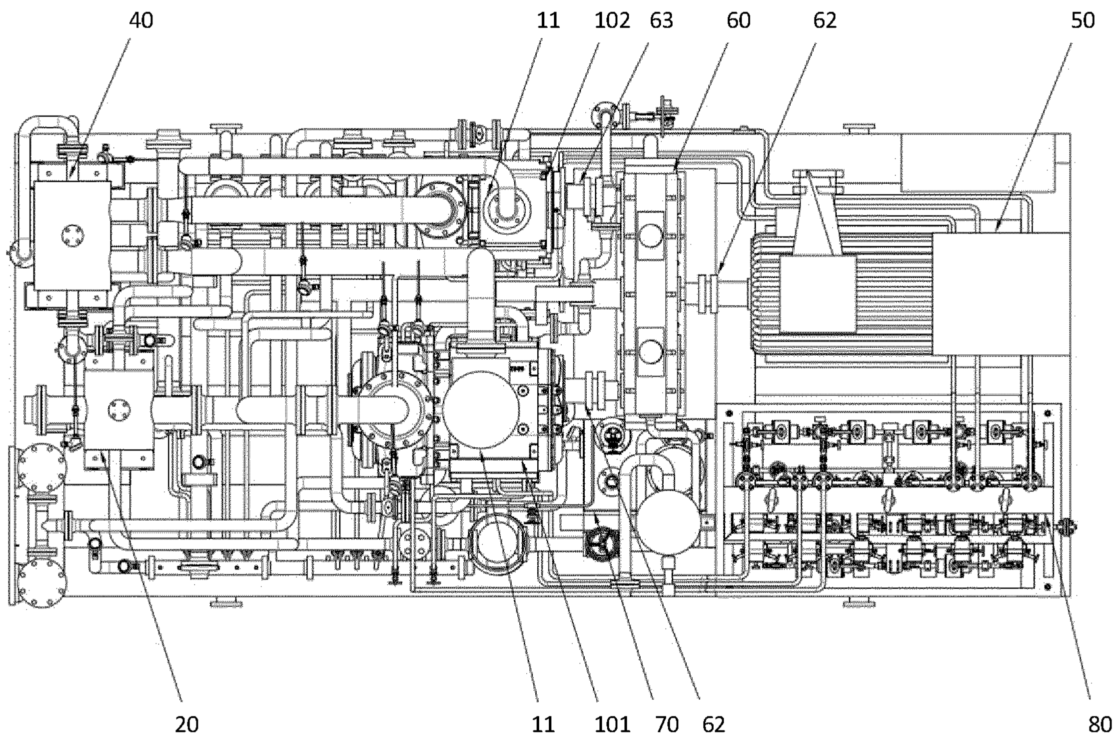

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No. **PCT/CN2024/089473**

A. CLASSIFICATION OF SUBJECT MATTER

F04C23/00(2006.01)i；F04C18/16(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT, VEN, CNKI: 螺杆, 螺旋, 压缩机, 齿轮, 二级, 两级, screw, spiral, comperssor, gear, two, double, stage

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 116517832 A (NO.711 RESEARCH INSTITUTE OF CHINA STATE SHIPBUILDING CORP., LTD.) 01 August 2023 (2023-08-01) claims 1-12, description, paragraphs 44-75, and figures 1-4	1-15
PX	CN 219974822 U (NO.711 RESEARCH INSTITUTE OF CHINA STATE SHIPBUILDING CORP., LTD.) 07 November 2023 (2023-11-07) description, paragraphs 39-71, and figures 1-6	1-15
X	CN 1892034 A (KOBE STEEL, LTD.) 10 January 2007 (2007-01-10) description, specific embodiments, and figures 1-2	1-4, 10-13, 15
Y	CN 1892034 A (KOBE STEEL, LTD.) 10 January 2007 (2007-01-10) description, specific embodiments, and figures 1-2	5-9, 14
Y	CN 115788830 A (NO.711 RESEARCH INSTITUTE OF CHINA STATE SHIPBUILDING CORP., LTD. et al.) 14 March 2023 (2023-03-14) description, paragraphs 2-64, and figure 1	5-9, 14
X	CN 109139456 A (NINGBO BAOSI ENERGY EQUIPMENT CO., LTD.) 04 January 2019 (2019-01-04) description, paragraphs 17-33, and figures 1-2	1, 13, 15

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 June 2024	**18 June 2024**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2024/089473

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017074266 A1 (KOBE STEEL, LTD.) 16 March 2017 (2017-03-16) description, paragraphs 45-58, and figures 1-4	1-2, 13, 15
X	CN 101321954 A (GHH RAND SCHRAUBENKOMPRESSOREN G.M.B.H.) 10 December 2008 (2008-12-10) description, specific embodiments, and figures 1-5	1, 13, 15
X	CN 108019349 A (ALMIG KOMPRESSOREN G.M.B.H. et al.) 11 May 2018 (2018-05-11) description, paragraphs 19-59, and figure 1	1, 13, 15
X	CN 203835726 U (INNOVATE (KUNSHAN) ENERGY MACHINERY CO., LTD.) 17 September 2014 (2014-09-17) description, paragraphs 13-20, and figure 1	1-2, 13, 15
A	CN 217501915 U (CHINA PETROLEUM & CHEMICAL CORP.) 27 September 2022 (2022-09-27) entire document	1-15

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/089473

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 116517832 A	01 August 2023	None	
CN 219974822 U	07 November 2023	None	
CN 1892034 A	10 January 2007	KR 20070005461 A	10 January 2007
		KR 100829665 B1	16 May 2008
		JP 2007040294 A	15 February 2007
		JP 4927446 B2	09 May 2012
CN 115788830 A	14 March 2023	None	
CN 109139456 A	04 January 2019	None	
US 2017074266 A1	16 March 2017	US 10167868 B2	01 January 2019
		WO 2015137028 A1	17 September 2015
		JP 2015169180 A	28 September 2015
		JP 6228868 B2	08 November 2017
		TW 201600724 A	01 January 2016
		TWI 586891 B	11 June 2017
		KR 20160118311 A	11 October 2016
		KR 101828200 B1	09 February 2018
CN 101321954 A	10 December 2008	ATE 498071 T1	15 February 2011
		ES 2359015 T3	17 May 2011
		EP 1957798 A1	20 August 2008
		EP 1957798 B1	09 February 2011
		US 2008286129 A1	20 November 2008
		HK 1127111 A1	18 September 2009
		WO 2007065487 A1	14 June 2007
		US 2008286138 A1	20 November 2008
		US 7690901 B2	06 April 2010
		WO 2007065486 A1	14 June 2007
		EP 1979618 A1	15 October 2008
		EP 1979618 B1	27 April 2016
		WO 2007065485 A1	14 June 2007
		US 2009004036 A1	01 January 2009
		US 7713039 B2	11 May 2010
		WO 2007065484 A1	14 June 2007
		DE 502006008894 D1	24 March 2011
		US 2013011285 A1	10 January 2013
		US 9091268 B2	28 July 2015
		EP 1957797 A1	20 August 2008
		EP 1957797 B1	28 September 2016
		EP 1957799 A1	20 August 2008
CN 108019349 A	11 May 2018	TW 201816272 A	01 May 2018
		TWI 663335 B	21 June 2019
		EP 3315779 A1	02 May 2018
		EP 3315779 B1	26 December 2018
		ES 2709763 T3	17 April 2019
		US 2018119601 A1	03 May 2018
		US 10626785 B2	21 April 2020
		PL 3315779 T3	31 May 2019
CN 203835726 U	17 September 2014	None	
CN 217501915 U	27 September 2022	None	

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 202310592731 **[0001]**