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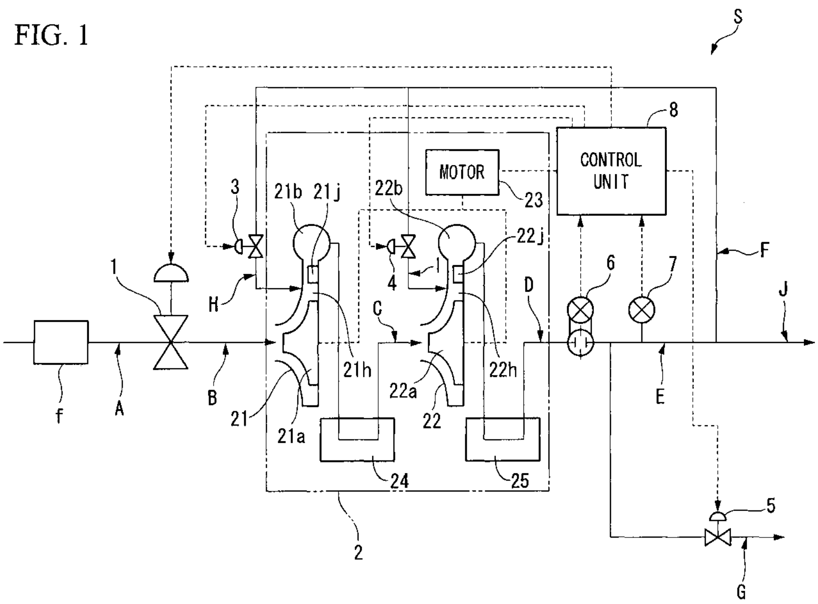
(54) GAS COMPRESSION DEVICE AND METHOD OF CONTROLLING GAS COMPRESSION DEVICE

(57) In a gas compression device that compresses gas by a compression means that is arranged in a plurality in series with respect to the flow direction of the gas, controlling the flow rate of the gas that is drawn into the gas compression portion in accordance with the demand amount of the gas of the demand end and, in the case of the flow rate of each compression means falling below a set value that is set based on the surging value, circulating and supplying at least a portion of the gas that is discharged from the gas compression portion to a diffuser of the compression means. For this reason, it is possible to sufficiently reduce the load of the driving means while suppressing the occurrence of surging in the compression means, and it is possible to reduce the consumption of energy.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a gas compression device that is provided with a plurality of compression means that are driven by a single drive means, and a method for controlling the gas compression device.

[0002] Priority is claimed on Japanese Patent Application No. 2007-188093, filed July 19, 2007, the content of which is incorporated herein by reference.

BACKGROUND ART

[0003] A turbo compression device (gas compression device) that is provided with a plurality of centrifugal compressors (compression means) that are linked by a shaft that is driven by a single motor (drive means) has conventionally been employed.

[0004] In such a turbo compression device, the plurality of centrifugal compressors are arranged in series in the flow direction of the gas, so that the gas is gradually compressed in each centrifugal compressor.

[0005] In a device (demand end) to which gas that is compressed (hereinbelow referred to as compressed gas) is supplied from the turbo compression device in a typical factory, the amount of compressed gas that is required (demand amount) changes with time. That is, the amount of the compressed gas that is supplied from the turbo compression device to a device at the demand end changes with time.

[0006] It is conceivable to respond to a decrease in the demand amount of the compressed gas by a method that decreases the amount of compressed gas by decreasing the intake amount of gas to the turbo compression device, and a method that always compresses a fixed amount of gas and supplies only the required amount to the device at the demand end and exhausts the remainder, but it is preferable to respond by a method that decreases the amount of compressed gas that is capable of reducing energy consumption in the turbo compression device (that is, capable of reducing the load on the motor).

[0007] In order to decrease the amount of compressed gas, it is necessary to decrease the flow rate of gas that flows in the turbo compression device. However, decreasing the flow rate of gas that flows in a centrifugal compressor beyond a certain limit gives rise to surging. In greater detail, when gas that is accelerated by an impeller in a centrifugal compressor is decelerated by a diffuser, the flow of this gas stalls, and this becomes a trigger of an occurrence of surging.

[0008] Therefore, in a conventional turbo compression device, by using a method that avoids surging in a centrifugal compressor such as disclosed in Patent Documents 1 to 4, the load on the motor is reduced while suppressing surging in the centrifugal compressor.

[Patent Document 1] Japanese Examined Patent Application Publication No. H02-61640
[Patent Document 2] Japanese Examined Patent Application Publication No. H02-59317
[Patent Document 3] Japanese Unexamined Utility Model Application Publication No. S59-99196
[Patent Document 4] Japanese Unexamined Patent Application Publication No. H10-252696

[0009] However, in a conventional centrifugal compressor, even if the art that is disclosed in Patent Documents 1 to 4 is employed, sufficiently suppressing surging is difficult in an environment in which the flow rate of the gas that is drawn into the centrifugal compressor is low, and it is not possible to decrease the flow rate of gas that is drawn into the centrifugal compressor to 60 to 70% or less. For this reason, it has not been possible to reduce the load on the motor to 60 to 70% or less.

[0010] The present invention was achieved in view of the above circumstances, and has as its object, in a gas compression device that compresses gas by a plurality of compression means that are arranged in series with respect to the gas flow direction, to reduce the energy consumption by sufficiently reducing the load of a drive means while suppressing the occurrence of surging in the compression means.

DISCLOSURE OF THE INVENTION

[0011] In order to achieve the aforementioned object, the gas compression device that is the first embodiment of the present invention is a gas compression device that arranges a plurality of compression means provided with impellers that impart velocity energy to a gas, and a diffuser that converts the velocity energy to pressure energy in series in the flow direction of gas, and supplies the gas that is compressed via the plurality of the compression means to a predetermined demand end, provided with a drive means that supplies power to the impeller; a flow rate adjusting means that adjusts the flow rate of the gas that is drawn into the compression means that is positioned furthest upstream with respect to the flow direction of the gas; a circulation and supply means that is capable of circulating and supplying at least a portion of the gas that is discharged from the compression means that is positioned furthest downstream with respect to the flow direction of the gas to the diffuser or is positioned between the diffuser and the impeller of each compression means, and a control means that controls at least the drive means, the flow rate adjusting means, and the circulation and supply means, in which the control means controls the flow rate adjusting means in accordance with a demand amount of the gas of the demand end, and in each compression means, in the case of the flow rate of the gas that is drawn in falling below a set value that is set based on a surging limit in the compression means, controls the circulation and supply means to circulate and supply a portion of the gas in the compression means.

[0012] According to this gas compression device, the flow rate adjusting means is controlled in accordance with the demand amount of gas of the demand end. That is, in the case of the demand amount of gas of the demand end decreasing, the flow rate of gas that is drawn into the gas compression device is reduced in accordance with this decrement.

[0013] In each compression means, in the case of the flow rate of the gas that is drawn in falling below a set value that is set based on a surging limit in the compression means, a portion of the gas in the compression means is circulated and supplied to the diffuser or between the diffuser and the impeller of each compression means.

[0014] The gas compression device may be provided with a pressure detecting means that detects the pressure of the gas that is discharged from the compression means that is positioned furthest downstream, and a flow rate detecting means that detects the flow rate of the gas that is discharged from the compression means that is positioned furthest downstream, and the control means may perform control of the flow rate adjusting means with at least the detection result of the pressure detecting means serving as the demand amount of the gas of the demand end, among the pressure detecting means and the flow rate detecting means.

[0015] The control means may start circulation and supply of the gas by the circulation and supply means in stages from the compression means that is positioned furthest downstream toward the upstream compression means.

[0016] The set value may be a value that matches the flow rate of the surging limit in the compression means and a predetermined margin.

[0017] The control means, in the case of the demand amount of the gas of the demand end being zero, may maintain the intake of the gas in the compression means that is positioned furthest upstream with respect to the flow direction of the gas, and exhaust a portion of the gas that is discharged from the compression means that is positioned furthest downstream with respect to the flow direction of the gas without supplying it to the demand end.

[0018] Next, a method of controlling a gas compression device that is the second embodiment of the present invention is a method of controlling a gas compression device that arranges a plurality of compression means provided with an impeller that imparts velocity energy to a gas and a diffuser that converts the velocity energy to pressure energy in series in the flow direction of gas, and supplies the gas that is compressed via the plurality of the compression means to a predetermined demand end, comprising the steps of: adjusting the flow rate of gas that is drawn into the compression means that is positioned furthest upstream with respect to the flow direction of the gas in accordance with a demand amount of the gas at the demand end, and in each compression means, circulating and supplying at least a portion of the gas that is discharged from the compression means that is positioned furthest downstream with respect to the flow direction of the gas to the diffuser or between the diffuser and the impeller of each compression means in the case of the flow rate of the gas that is drawn in falling below a set value that is set based on a surging limit in the compression means.

[0019] According to this method of controlling a gas compression device, in accordance with a demand amount of the gas at the demand end, the flow rate of the gas that is drawn into the gas compression device is controlled. That is, in the case of the demand amount of the gas at the demand end device having decreased, the flow rate of the gas that is drawn into the gas compression device is reduced in proportion to this decrement.

[0020] In each compression means, in the case of the flow rate of the gas that is drawn in falling below a set value that is set based on a surging limit in the compression means, in the compression means, a portion of the gas that is discharged from the compression means that is positioned furthest downstream is circulated and supplied to the diffuser or between the diffuser and the impeller of each compression means.

[0021] Detecting the pressure and the flow rate of the gas that is discharged from the compression means that is positioned furthest downstream and, among the detection result, controlling the flow rate of the gas that is drawn into the compression means that is positioned furthest upstream may be performed with at least the pressure serving as the demand amount of the gas at the demand end.

[0022] The circulation and supply of the gas may be started in stages from the compression means that is positioned furthest downstream toward the upstream compression means.

[0023] The set value may be a value that matches the flow rate of the surging limit in the compression means and a predetermined margin.

[0024] In the case of the demand amount of the gas at the demand end being zero, maintaining the intake of the gas in the compression means that is positioned furthest upstream with respect to the flow direction of the gas, and exhausting a portion of the gas that is discharged from the compression means that is positioned furthest downstream with respect to the flow direction of the gas without supplying it to the demand end may be performed.

Effect of the Invention

[0025] According to the gas compression device and the method of controlling the gas compression device of the present invention, the flow rate of gas that is drawn into the gas compression device is controlled in accordance with the demand amount of gas at the demand end. That is, in the case of the demand amount of the gas at the demand end device having decreased, the flow rate of the gas that is drawn into the gas compression device is reduced in proportion to this decrement.

[0026] In each compression means, in the case of the flow rate of the gas that is drawn in falling below a set value that is set based on a surging limit in the compression means, in the compression means, a portion of the gas that is discharged from the compression means that is positioned furthest downstream is circulated and supplied to the diffuser or between the diffuser and the impeller of each compression means.

[0027] Here, the gas that is circulated and supplied flows to the diffuser without being supplied to the impeller. For this reason, it is possible to supply gas of a sufficient flow rate to the diffuser without increasing the load on the impeller, and it is possible to suppress the occurrence of stalling and the occurrence of surging without increasing the load to the drive means. That is, however low the flow rate of the gas that is drawn into each compression means, it is possible to cause a flow of gas with a flow rate that enables suppression of surging to the diffuser of the compression means.

[0028] Accordingly, according to the present invention, in a gas compression device that compresses gas by a plurality of compression means that are provided in series with respect to the flow direction of gas, it is possible to reduce energy consumption by sufficiently reducing the load of the drive means while suppressing the occurrence of surging in the compression means.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

FIG 1 is a block drawing that shows the outline constitution of a turbo compression device that is one embodiment of the present invention.

FIG 2 is a cross-sectional view of a centrifugal compressor that is provided in the turbo compression device that is one embodiment of the present invention.

FIG. 3 is a table that shows the flow distribution of gas in the turbo compression device that is one embodiment of the present invention.

FIG. 4 is a graph that shows the load changes of a motor that is provided in the turbo compression device that is one embodiment of the present invention.

FIG 5 is a schematic drawing that shows a modification of the turbo compression device that is one embodiment of the present invention.

FIG. 6 is a schematic drawing that shows a modification of the turbo compression device that is one embodiment of the present invention.

FIG. 7 is a schematic drawing that shows a modification of the turbo compression device that is one embodiment of the present invention.

Description of Reference Numerals

[0030] 1 inlet guide vane (flow rate adjusting means, 2 gas compression portion, 21 first centrifugal compressor (compression means), 22 second centrifugal compressor (compression means), 23 motor (drive means), 3 first circulation and supply control valve (circulation and supply means), 4 second circulation and supply control valve (circulation and supply means), 5 discharge valve, 6 flow rate detector (flow rate detecting means), 7 pressure detector (pressure detecting means), 8 control device (control means), 21a, 22a impeller, 21h, 22h diffuser, s turbo compression device (gas compression device)

BEST MODE FOR CARRYING OUT THE INVENTION

[0031] Hereinbelow, an embodiment of a gas compression device and a method of controlling the gas compression device according to the present invention shall be described with reference to the drawings. In the following drawings, the scale of each member shall be suitably changed in order to make each member a recognizable size.

[0032] FIG 1 is a block drawing that shows the outline constitution of a turbo compression device S (gas compression device) of the present embodiment.

[0033] As shown in the drawings, the turbo compression device S of the present embodiment is provided with an inlet guide vane 1 (flow rate adjusting means), a gas compression portion 2, a first circulation and supply control valve 3 (circulation and supply means), a second circulation and supply control valve 4 (circulation and supply means), an exhaust control valve 5, a flow rate detector 6 (flow rate detecting means), a pressure detector 7 (pressure detecting means), and a control unit 8 (control means).

[0034] The inlet guide vane 1 is for adjusting the flow rate of gas that is drawn into the gas compression portion 2, and is controlled by the control unit 8. Although described in full detail below, the gas compression portion 2 has a constitution in which two (a plurality of) centrifugal compressors 21 and 22 (compression means) are arranged in series in the flow direction of the gas. The gas that is drawn into the gas compression portion 2 via the inlet guide vane 1 is first drawn into the centrifugal compressor 21 that is positioned on the upstream side (furthest upstream) with respect to the flow direction of the gas. That is, the inlet guide vane 1 adjusts the flow rate of gas that is drawn into the centrifugal compressor 21 that is positioned furthest upstream with respect to the gas flow direction.

[0035] This inlet guide vane 1 imparts a twist to the gas in the same direction as the rotation direction of an impeller 21a (refer to FIG. 2) that the centrifugal compressor 21 is equipped with. Thereby, the workload of the impellor of the centrifugal compressor 21 is decreased.

[0036] As a substitute for the inlet guide vane 1, it is also possible to use a butterfly valve. In this case, the flow rate of the gas that is drawn in is adjusted by applying resistance to the gas without imparting a twist to the gas.

[0037] The gas compression portion 2 is provided with two centrifugal compressors 21 and 22 (compression means) that are arranged in the gas flow direction, a motor 23 (drive means) that supplies rotation power to the impellers 21a and 22a that are provided in the centrifugal compressors 21 and 22, an intercooler 24 that cools the gas that is discharged from the centrifugal compressor 21 (hereinbelow referred to as the first centrifugal compressor 21) located on the upstream side with respect to the flow direction of the gas, and an aftercooler 25 that cools the gas that is discharged from the centrifugal compressor 22 (hereinbelow referred to as the second centrifugal compressor 22) located on the downstream side with respect to the flow direction of the gas.

[0038] The first centrifugal compressor 21 and the second centrifugal compressor 22 compress and discharge the gas that is drawn in. FIG 2 is a cross-sectional view for describing the outline constitution of the first centrifugal compressor 21 and the second centrifugal compressor 22. Since the first centrifugal compressor 21 and the second centrifugal compressor 22 have the same constitution, in FIG. 2, only one centrifugal compressor is shown. Also, in FIG 2, reference numerals without parentheses refer to the first centrifugal compressor 21, while reference numerals with parentheses refer to the second centrifugal compressor 22.

[0039] As shown in FIG. 2, the centrifugal compressor 21 (22) is provided with a casing main body 21c (22c) that has a scroll flow path 21b (22b) of which one side opens and extends in the circumferential direction toward the portion in the vicinity of the inner peripheral edge, a gas discharge pipe 21d (22d) that is provided at a predetermined location of the casing main body 21c so as to continue to the scroll flow path 21b (22b), a rotor shaft 21f(22f) that rotatably passes through a seal member 21e (22e) that is provided in the center of the other wall portion of the casing main body 21c (22c), an impeller 21a (22a) that is positioned in the center in the inner portion of the casing main body 21c (22c) and that is coupled to the rotor shaft 21f(22f), a ring-shaped casing lid 21i (22i) that fits in the opening portion of the casing main body 21c (22c) so as to cover this impeller 21a (22a) and that forms a diffuser 21h (22h) that continues from a gas inflow port 21g (22g) that heads from the outer portion to the distal end of the impeller 21a (22a) and from the circumferential edge portion of the impeller 21a (22a) to the scroll flow path 21b (22b), and a plurality of diffuser vanes 21j (22j) that are disposed at equal intervals in the circumferential direction in the diffuser 21h (22h).

[0040] The rotor shaft 21f of the first centrifugal compressor 21 and the rotor shaft 22f of the second centrifugal compressor 22 are each connected with the motor 23 via a gearwheel acceleration mechanism. Then the impeller 21a (22a) rotates at a rotation speed corresponding to the output of the motor 23.

[0041] Also, the diffuser vane 21j (22j) is integrally formed with respect to the ring-shaped vane support seat 211 (221) that is installed in a cavity portion 21k (22k) that is provided so as to surround the impeller 21a (22a) in the interior of the casing main body 21c (22c).

[0042] Also, the flow path cross-sectional shape of the scroll flow path 21b (22b) is formed so as to become larger as the gas discharge pipe 21d (22d) is approached.

[0043] Moreover, in the centrifugal compressor 21 (22), a plurality of bypass flow passage holes 21m (22m) that are positioned between the impeller 21a (22a) and the diffuser vane 21j (22j) are formed in the casing lid 21i (22i). This bypass flow passage hole 21m (22m) is a flow passage for flowing gas from the outside of the centrifugal compressor 21 (22) toward the front edge side of the diffuser vane 21j (22j) of the diffuser 21h (22h). The plurality of bypass flow passage holes 21m (22m) are formed in the rotation direction of the impeller 21a (22a). That is, the diffuser 21h (22h) and the outside are connected by the plurality of bypass flow passages 21m (22m).

[0044] In this kind of centrifugal compressor 21 (22), velocity energy is imparted by the rotatively driven impeller 21a (22a) to the gas that has flowed in from the gas inflow port 21g (22g). Then, the velocity energy that is imparted to the gas is converted to pressure energy by the diffuser vane 21j (22j). Thereby, the gas is compressed, and the compressed gas is discharged to the outside of the centrifugal compressor 21 (22) via the scroll flow path 21b (22b). Then, the gas that flows in via the bypass flow passage holes 21m (22m), without being supplied to the impeller 21a (22a), is supplied to the diffuser vane 21j (22j) along with the gas to which the velocity energy has been imparted by the impeller 21a (22a).

[0045] Although FIG 1 shows the diffuser vane 21j (22j) and the scroll flow path 21b (22b) only on one side of the impeller 21a (22a) for convenience, they exist in reality along the entire periphery. The bypass flow passage holes 21m (22m) are formed at equal intervals between the impeller 21a (22a) and the diffuser vane 21j (22j) that exists along the entire periphery, and are constituted such that gas is uniformly supplied to each bypass flow passage hole 21m (22m).

[0046] Returning to FIG. 1, the motor 23 is connected to the impeller 21a and the impeller 22a, and the impeller 21a and impeller 22a are made to rotate at a constant rotational frequency. As this kind of motor 23, it is possible to use an induction motor, for example.

[0047] The first circulation and supply control valve 3 serves to enable circulation and supply of a portion or all of the gas that is discharged from the gas compression portion 2 to the bypass flow passage holes 21m of the first centrifugal compressor 21 (that is, between the impeller 21a and the diffuser vane 21j).

[0048] The opening degree of the first circulation and supply control valve 3 is made to be controllable by the control unit 8. As the opening degree of the first circulation and supply control valve 3 is adjusted, the flow rate of gas that is supplied to the bypass flow passage holes 21m is adjusted.

[0049] The second circulation and supply control valve

4 serves to enable circulation and supply of a portion or all of the gas that is discharged from the gas compression portion 2 to the bypass flow passage holes 22m of the second centrifugal compressor 22 (that is, between the impeller 22a and the diffuser vane 22j).

[0050] The opening degree of the second circulation and supply control valve 4 is made to be controllable by the control unit 8. As the opening degree of the second circulation and supply control valve 4 is adjusted, the flow rate of gas that is supplied to the bypass flow passage holes 21m is adjusted.

[0051] The exhaust control valve 5 serves to exhaust a portion or all of the gas that is discharged from the gas compression portion 2 to the outside of the turbo compression device S, and its opening and closing can be controlled by the control unit 8.

[0052] The flow rate detector 6 has a measuring instrument that measures the flow of the gas that is discharged from the gas compression portion 2, and a transmitter that outputs the measurement result of the measuring instrument as a signal that shows the flow rate of the gas that has been discharged from the gas compression portion 2 (that is, the flow rate of the gas that has been discharged from the second centrifugal compressor 22).

[0053] The pressure detector 7 has a measuring instrument that measures the pressure of the gas that is discharged from the gas compression portion 2 (that is, the pressure of the gas that has been discharged from the second centrifugal compressor 22), and a transmitter that outputs the measurement result of the measuring instrument as a signal that shows the pressure of the gas that has been discharged from the gas compression portion 2.

[0054] The control unit 8 is electrically connected with the inlet guide vane 1 (or the butterfly valve), the motor 23 of the gas compression portion 2, the first circulation and supply control valve 3, the second circulation and supply control valve 4, the exhaust control valve 5, the flow rate detector 6, and the pressure detector 7.

[0055] In this kind of turbo compression device S of the present embodiment, the gas that is drawn in from the outside via the filter f or the like is compressed and discharged by the gas compression portion 2. Then, of the gas that is discharged from the gas compression portion 2, the gas that excludes the gas that is supplied to the first centrifugal compressor 21 via the first circulation and supply control valve 3, the gas that is supplied to the second centrifugal compressor 22 via the second circulation and supply control valve 4, and the gas that is exhausted to the outside via the exhaust control valve 5 is supplied to the device at the demand end.

[0056] The control unit 8 first compares the detection result of the pressure detector 7 and a set value that is determined in advance, and controls the inlet guide vane 1.

[0057] Described in greater detail, in the case of the pressure of the gas after the gas compression portion 2 being a desired pressure set value that is set in advance, the flow rate of the gas that is supplied from the turbo compression device S to the demand end device and the flow rate of the gas that the demand end device requires are shown to be the same. In the case of the gas flow rate that the demand end device requires having changed, the balance between the gas flow rate that is supplied from the turbo compression device S to the demand end device and the gas flow rate that the demand end device requires is disturbed, and the pressure of the gas that is discharged from the gas compression portion 2 changes.

[0058] For this reason, the control unit 8 compares the detection result of the pressure detector 7 and the set value that is determined in advance, and controls the inlet guide vane 1 so as to become the aforementioned desired pressure. As a result, the flow rate of the gas supplied from the turbo compression device S to the demand end device can be matched to the gas flow rate that the demand end device requires.

[0059] Thus, the pressure of the gas after the gas compression portion 2 (the pressure of the gas that is discharged from the compression means that is located furthest downstream) relates to the flow rate of the gas supplied from the turbo compression device S to the demand end device. That is, controlling the inlet guide vane 1 based on the detection result of the pressure detector 7 is controlling the inlet guide vane 1 based on the flow rate of gas that is supplied from the turbo compression device S to the demand end device.

[0060] When the detection result of the pressure detector 7 has become the desired pressure, the control unit 8 checks the flow rate of the gas discharged from the gas compression portion 2, from the detection result of the flow rate detector 6. In addition to the detection result of the pressure detector 7, control of the inlet guide vane 1 may be performed using the detection result of the flow rate detector 6.

[0061] When rapid control of the inlet guide vane 1 is not required, it is also possible to directly measure the flow rate of the gas that is supplied to the demand end device, and to change this measuring result to the detection result of the pressure detector 7.

[0062] As a result of the control of the inlet guide vane 1, in the case of the flow rate of the gas that is drawn into the centrifugal compressors 21 and 22 falling below the set value that is set based on the surging limit in the centrifugal compressors 21 and 22 that is stored in advance, by controlling the first circulation and supply control valve 3 and/or the second circulation and supply control valve 4, the control unit 8 circulates and supplies a portion of the gas that is discharged from the gas compression portion 2 to the first centrifugal compressor 21 and/or the second centrifugal compressor 22.

[0063] First, in the second centrifugal compressor 22, when the flow rate of the gas that is drawn in via the first centrifugal compressor 21 falls below the set value that is set based on a surging limit, the control unit 8 controls the second circulation and supply control valve 4 to circulate and supply a portion of the gas that is discharged from the gas compression portion 2 between the impeller 22a and the diffuser vane 22j of the second centrifugal compressor 22 (that is, the diffuser 21h (22h). Then, in the first centrifugal compressor 21, when the flow rate of the gas that is drawn in via the inlet guide vane 1 falls below the set value that is set based on a surging limit, the control unit 8 controls the first circulation and supply control valve 3 to circulate and supply a portion of the gas that is discharged from the gas compression portion 2 between the impeller 21a and the diffuser vane 21j of the first centrifugal compressor 21 (that is, the diffuser 21h (22h).

[0064] In the turbo compression device S of the present embodiment, the set value that is set based on the surging limit is a value that matches the flow rate of the surging limit and the predetermined margin. Moreover, the flow rate of the surging limit shows the minimum limit gas flow rate at which surging does not occur in each centrifugal compressor S.

[0065] The flow rate of the gas that is drawn into the first centrifugal compressor 21 corresponds to the opening of an inlet guide vane 1. Moreover, the flow rate of the gas that is drawn into the second centrifugal compressor 22 corresponds to the opening of the inlet guide vane 1 and the opening of the first circulation and supply control valve 3. The opening of the first circulation and supply control valve 3 is controlled based on the opening of an inlet guide vane 1. For this reason, the flow rate of the gas drawn into the centrifugal compressors 21 and 22 is uniquely determined corresponding to the opening of an inlet guide vane 1.

[0066] Moreover, the control unit 8 exhausts gas to the outside by opening the exhaust control valve 5 while maintaining the drawing in of the gas in the gas compression portion 2 via the inlet guide vane 1 in the case of the quantity of gas demanded by the demand end device being zero.

[0067] That is, even if the demand amount of gas of the demand end device is zero, the control device 8 maintains the operation of the turbo compression device S at the minimum energy consumption without completely closing the inlet guide vane 1.

[0068] In the turbo compression device S of the present embodiment that is constituted in this manner, the gas that is drawn in from the outside is drawn into the turbo compression device S via the inlet guide vane 1, and is drawn into the gas compression portion 2. In the gas compression portion 2, the gas is compressed in the first centrifugal compressor 21, is subsequently cooled by the intercooler 24, and is further compressed in the second centrifugal compressor 22, and thereafter cooled and discharged by the aftercooler 25.

[0069] The gas that is discharged from the gas compression portion 2 is distributed corresponding to the opening of the first circulation and supply control valve 3, the second circulation and supply control valve 4, and the exhaust control valve 5, with the remainder being supplied to the demand end device.

[0070] The gas that is distributed by the first circulation and supply control valve 3 is supplied as required between the impeller 21a and the diffuser vane 21j of the first centrifugal compressor 21. Also, the gas that is distributed by the second circulation and supply control valve 4 is supplied between the impeller 22a and the diffuser vane 22j of the second centrifugal compressor 22. Also, the gas that is distributed by the exhaust control valve 5 is exhausted to the outside.

[0071] Next, the specific operation (control method) of the turbo compression device S of the present embodiment constituted in this manner shall be described with reference to FIG 3 and FIG. 4. In the following description, (flow rate %) refers to the weight flow rate % of the gas, and the flow rate at each place is assumed to be 100 flow rate % in the case of the inlet guide vane 1 being opened to its maximum extent.

[0072] Also, FIG 3 is a table that shows the (flow rate %) at each position A to I in correspondence with the (flow rate %) of the gas supplied to the demand end device. FIG. 4 is a graph that shows the relationship between the demand flow amount to the demand end device and the motor load. As shown in FIG 1, A is the upstream side position of the inlet guide vane 1, B is the position between the inlet guide vane 1 and the first centrifugal compressor 21, C is the position between the centrifugal compressor 21 and the second centrifugal compressor 22, D is the position on the downstream side of the second centrifugal compressor 22, E is the position on the downstream side of the second centrifugal compressor 22 and the position after the removal of the gas to be exhausted via the exhaust control value 5, F is the position on the downstream side of the second centrifugal compressor 22 and is the position that is divided to the side of the first circulation and supply control valve 3 and the second circulation and supply control valve 4, G is the position on the downstream side of the of the exhaust control valve, H is the position between the first circulation and supply control valve 3 and the first centrifugal compressor 21, I is the position between the second circulation and supply control valve 4 and the second centrifugal compressor 22, and J is the position just before the demand end.

[0073] Also, in the present embodiment, the set value based on the surging limit of the first centrifugal compressor 21 is 60 flow rate %, and the set value based on the surging limit of the second centrifugal compressor 22 is 70 flow rate %.

[0074] First, in the case of the demand flow rate of the demand end device being 100 flow rate % (that is, in the case of the flow rate at J being 100 flow rate %), the inlet guide vane 1 is opened to a maximum, and thereby the flow rate at A to D becomes 100 flow rate %. Then, the control unit 8, in the case of the demand flow rate of the demand end device being 100 flow rate %, makes the output of the motor 23 100% and puts the first circulation and supply control valve 3, the second circulation and supply control valve 4, and the exhaust control valve 5 in a closed state. As a result, the flow rate at E becomes 100 flow rate %, while the flow rates at F to I become 0 flow rate %. That is, in the case of the demand flow rate of the demand end device being 100 flow rate %, all of the gas is supplied to the demand end device, and there is no circulation and supply to the first centrifugal compressor 21 and the second centrifugal compressor 22.

[0075] Then, in the case of the demand flow rate of the demand end device being 100 flow rate %, since the flow rate of the gas that is drawn into the first centrifugal compressor 21 and the flow rate of the gas that is supplied to the second centrifugal compressor 22 become 100 flow rate %, the load of the motor 23 also becomes 100% as shown in FIG. 4.

[0076] In the case of the demand flow rate of the demand end device being 70 flow rate % (that is, in the case of the flow rate at J being 70 flow rate %), the control unit 8 restricts the opening of the inlet guide vane 1 to make the flow rate at A 70 flow rate %. In this case, the flow rate at B to D also becomes 70 flow rate %. Then, the control unit 8, in the case of the demand flow rate of the demand end device being 70 flow rate %, puts the first circulation and supply control valve 3, the second circulation and supply control valve 4, and the exhaust control valve 5 in a closed state. As a result, the flow rate at E becomes 70 flow rate %, and the flow rate at F to I becomes 0 flow rate %. That is, in the case of the demand flow rate of the demand end device being 70 flow rate %, all of the gas is supplied to the demand end device, and there is no circulation and supply to the first centrifugal compressor 21 and the second centrifugal compressor 22.

[0077] Then, in the case of the demand flow rate of the demand end device being 70 flow rate %, since the flow rate of the gas that is drawn into the first centrifugal compressor 21 and the flow rate of the gas that is draw into the second centrifugal compressor 22 become 70 flow rate %, the load of the motor 23 also becomes 70% as shown in FIG 4.

[0078] In the case of the demand flow rate of the demand end device being 60 flow rate % (that is, in the case of the flow rate at J being 60 flow rate %), the control unit 8 restricts the opening of the inlet guide vane 1 to make the flow rate at A 60 flow rate %. In this case, when the second circulation and supply control valve 4 remains closed, since the flow rate of the gas that is drawn into the second centrifugal compressor 22 is less than 70 flow rate % that is the set value, the control unit 8 opens up the second circulation and supply control valve 4 so that a 10 flow rate % portion of the gas that is discharged from the gas compression portion 2 is circulated and supplied to the second centrifugal compressor 22. The first circulation and supply control valve 3 and the exhaust control valve 5 remain closed. As a result, the flow rate at B and C becomes 60 flow rate %, the flow rate at D and E becomes 70 flow rate %, the flow rate at F and I becomes 10 flow rate %, and the flow rate at G and H becomes 0 flow rate %.

[0079] In the second centrifugal compressor 22, since the flow rate in the diffuser 22h becomes 70 flow rate %, it is possible to suppress the occurrence of surging in the second centrifugal compressor 22.

[0080] Meanwhile, since the flow rate in the impeller 22a and the flow rate of the impeller 21a of the first centrifugal compressor 21 are 60 flow rate %, it is possible to reduce the load of the motor 23 to approximately 60% as shown in FIG. 4.

[0081] In the case of the demand flow rate of the demand end device being 50 flow rate % (that is, in the case of the flow rate at J being 50 flow rate %), the control unit 8 restricts the opening of the inlet guide vane 1 to make the flow rate at A 50 flow rate %. In this case, when the first circulation and supply control valve 3 and the second circulation and supply control valve 4 remain closed, since the flow rate of the gas that is drawn into the first centrifugal compressor 21 and the second centrifugal compressor 22 respectively falls below 60 flow rate % and 70 flow rate %, which are the set values, the control unit 8 opens up the first circulation and supply control valve 3 and the second circulation and supply control valve 4 so that, of the gas that is discharged from the gas compression portion 2, 10 flow rate % is circulated and supplied to the first centrifugal compressor 21 and a 10 flow rate % portion is circulated and supplied to the second centrifugal compressor 22. The exhaust control valve 5 remains closed. As a result, the flow rate at B becomes 50 flow rate %, the flow rate at C becomes 60 flow rate %, the flow rate at D and E becomes 70 flow rate %, the flow rate at F becomes 20 flow rate %, the flow rate at G becomes 0 flow rate %, and the flow rate at H and I becomes 10 flow rate %.

[0082] In the first centrifugal compressor 21, since the flow rate in the diffuser 21h becomes 60 flow rate %, and in the second centrifugal compressor 22, the flow rate in the diffuser 22h becomes 70 flow rate %, it is possible to suppress the occurrence of surging in the first centrifugal compressor 21 and the second centrifugal compressor 22.

[0083] Meanwhile, since the flow rate in the impeller 21a becomes 50 flow rate % and the flow rate in the impeller 22a becomes 60 flow rate %, the load on the motor 23 is further reduced compared to the case of the demand flow rate of the demand end device being 60 flow rate % as shown in FIG. 4.

[0084] In the case of the demand flow rate of the demand end device being 10 flow rate % (that is, in the case of the flow rate at J being 10 flow rate %), the control unit 8 restricts the opening of the inlet guide vane 1 to make the flow rate at A 10 flow rate %. In this case, when the first circulation and supply control valve 3 and the second circulation and supply control valve 4 remain closed, since the flow rate of the gas that is drawn into the first centrifugal compressor 21 and the second centrifugal compressor 22 respectively falls below 60 flow rate %

and 70 flow rate %, which are the respective set values, the control unit 8 opens up the first circulation and supply control valve 3 and the second circulation and supply control valve 4 so that, of the gas that is discharged from the gas compression portion 2, 50 flow rate % is circulated and supplied to the first centrifugal compressor 21 and a 10 flow rate % portion is circulated and supplied to the second centrifugal compressor 22. The exhaust control valve 5 remains closed. As a result, the flow rate at B becomes 10 flow rate %, the flow rate at C becomes 60 flow rate %, the flow rate at D and E becomes 70 flow rate %, the flow rate at F becomes 60 flow rate %, the flow rate at G becomes 0 flow rate %, the flow rate at H becomes 50 flow rate %, and the flow rate at I becomes 10 flow rate %.

[0085] In the first centrifugal compressor 21, since the flow rate in the diffuser 21h becomes 60 flow rate %, and in the second centrifugal compressor 22, the flow rate in the diffusers 22h becomes 70 flow rate %, it is possible to suppress the occurrence of surging in the first centrifugal compressor 21 and the second centrifugal compressor 22.

[0086] Meanwhile, since the flow rate in the impeller 21a becomes 10 flow rate % and the flow rate in the impeller 22a becomes 60 flow rate %, the load on the motor 23 is further reduced compared to the case of the demand flow rate of the demand end device being 50 flow rate % as shown in FIG 4.

[0087] In the case of the demand flow rate of the demand end device being 0 flow rate % (that is, in the case of the flow rate at J being 0 flow rate %), the control unit 8, similarly to the case of the demand flow rate of the demand end device being 10 flow rate %, opens up the first circulation and supply control valve 3 and the second circulation and supply control valve 4 so that, of the gas that is discharged from the gas compression portion 2, 50 flow rate % is circulated and supplied to the first centrifugal compressor 21 and a 10 flow rate % portion is circulated and supplied to the second centrifugal compressor 22. Then, it is opened via the exhaust control valve 5, and the output of the motor 23 is maintained at 10%. As a result, the flow rate at B becomes 10 flow rate %, the flow rate at C and E becomes 60 flow rate %, the flow rate at D becomes 70 flow rate %, the flow rate at F becomes 60 flow rate %, the flow rate at G becomes 10 flow rate %, the flow rate at H becomes 50 flow rate %, and the flow rate at I becomes 10 flow rate %.

[0088] In the turbo compression device S of this embodiment, the circulation and supply of gas is started in stages from the second centrifugal compressor 22 that is positioned furthest downstream to the first centrifugal compressor 21 that is upstream.

[0089] According to the turbo compression device and the control method of the turbo compression device of the present embodiment, the flow rate of gas that the turbo compression device S draws in is controlled in proportion to the gas demand flow rate (demand amount) of the demand end device. That is, in the case of the gas demand flow rate of the demand end device having decreased, the flow rate of the gas that the turbo compression device S draws in is reduced in proportion to this amount of decrease.

[0090] In each centrifugal compressor 21 and 22, in the case of the flow rate of the gas that is drawn in falling below a set value that is set based on the surging limit in the centrifugal compressor 21 and 22, a portion of the gas that is discharged from the gas compression portion 2 in the centrifugal compressors 21 and 22 concerned is circulated and supplied to the diffusers 21h and 22h of the centrifugal compressors 21 and 22, respectively, so that surging is suppressed.

[0091] Here, the gas that is circulated and supplied flows to the diffusers 21h and 22h without being supplied to the impellers 21a and 22a. For this reason, it is possible to supply gas at a sufficient flow rate to the diffusers 21h and 22h without increasing the load on the impellers 21a and 22a, and it is possible to suppress the occurrence of surging without increasing the load on the motor. That is, however low the flow rate of the gas that is drawn into the first centrifugal compressor 21, it is possible to cause a flow of gas with a flow rate that enables suppression of surging to the diffusers 21h and 22h of the respective centrifugal compressors 21 and 22.

[0092] Accordingly, according to the present embodiment, in the turbo compression device that compresses gas by the centrifugal compressors 21 and 22 that are arranged in a plurality in series in the flow direction of the gas, it is possible to reduce energy consumption by sufficiently reducing the load of the motor while suppressing the occurrence of surging in the centrifugal compressors 21 and 22.

[0093] Also, according to the turbo compression device and the method of controlling the turbo compression device of the present embodiment, in the case of the gas demand flow rate of the demand end device being zero, in addition to maintaining the drawing in of the gas in the gas compression portion 2, a portion of the gas that is discharged from the gas compression portion 2 (that gas that is not circulated and supplied among the gas that is discharged from the gas compression portion 2) is exhausted without supplying to the demand end device. For this reason, even in the case of the gas demand flow rate of the demand end device being zero, it is possible to maintain the operation of the turbo compression device S with minimal energy consumption without completing closing the inlet guide vane 1. Therefore, it is possible to reopen the supply quickly in the case of the supply of gas to the demand end device once again being required.

[0094] Also, according to the turbo compression device and the method of controlling the turbo compression device of the present embodiment, a value that relates to the centrifugal compressor 21 and the centrifugal compressor 22 that is stored in advance in the control unit 8 is made a value that matches the flow rate at the surging limit in the centrifugal compressors 21 and 22 and a predetermined margin. For this reason, after imparting a margin to the flow rate of the surging limit, since the gas is circulated and supplied to the centrifugal compressors 21 and 22, it is possible to reliably suppress the occurrence of surging.

[0095] Also, generally in the gas compression portion 2, since the centrifugal compressor that is positioned on the downstream side with respect to the gas flow direction has a smaller flow rate coefficient, gas is circulated and supplied first to the centrifugal compressor that is positioned on the downstream side. However, for example by setting the margin in the set value that relates to the first centrifugal compressor 21 to be greater than the margin in the set value that relates to the second centrifugal compressor 22, it becomes possible to start the circulation and supply of the gas to the centrifugal compressors 21 and 22 simultaneously, and so it becomes possible to streamline the control.

[0096] Hereinabove, a preferred embodiment of a gas compression device and a method of controlling the gas compression device according to the present invention were described with reference to the drawings, but needless to say the present invention is not to be considered as being limited by the aforementioned embodiment. The shapes and combinations of the constituent elements shown in the abovementioned embodiment are but one example, and various modifications based on design requirements are possible without departing from the spirit or scope of the present invention.

[0097] For example, in the aforementioned embodiment, the case was described of the turbo compression device being provided with two centrifugal compressors.

[0098] However, the present invention is not limited to this, and there may be three or more centrifugal compressors. In this case as well, for example, by suitably setting a margin in the aforementioned set value that relates to each centrifugal compressor, a constitution may be adopted that circulates and supplies gas simultaneously to a number of centrifugal compressors.

[0099] In the case of three centrifugal compressors being provided, specifically, as shown in the schematic drawing of FIG 5 the circulation and supply of gas may be started in stages in the order of a centrifugal compressor X3 that is furthest downstream, a centrifugal compressor X2 that is mid stream, and a centrifugal compressor X1 that is furthest upstream, as shown in the schematic drawing of FIG. 6, the circulation and supply may be simultaneously started to the centrifugal compressor X3 that is furthest downstream, the centrifugal compressor X2 that is mid stream, and the circulation and supply may be subsequently started to the centrifugal compressor X1 that is furthest upstream, and as shown in the schematic drawing of FIG 7, the circulation and supply may be simultaneously started to the centrifugal compressor X2 that is mid stream and the centrifugal compressor X1 that is furthest upstream after starting the circulation and supply to the centrifugal compressor X3 that is furthest downstream.

[0100] Since the pressure means that is furthest downstream has a small flow rate coefficient and enters a surge first, in any event the circulation and supply to the centrifugal compressor that is located on the downstream side is started first, and thereafter the circulation and supply to the centrifugal compressor that is located on the upstream side is started.

[0101] Also, in the aforementioned embodiment, the constitution was described of directly measuring the flow rate of the gas discharged from the gas compression portion 2 by the flow rate detector 6 and, based on this measurement result, the control unit 8 acquiring the demand amount of gas of the demand end device.

[0102] However, the present invention is not limited to this, and in place of the flow rate detector 6, the current consumption or power consumption of the motor 23 may be measured, and thereby the flow rate of the gas discharged from the gas compression portion 2 may be indirectly measured. With such a constitution, it is possible to acquire the demand amount of gas of the demand end device based on the measurement result.

[0103] Also, in the aforementioned embodiment, a constitution provided with the centrifugal compressors 21 and 22 as the compression means of the present invention was described.

[0104] However, the present invention is not limited thereto, and it is possible to use an axial flow compressor as the compression means of the present invention.

[0105] Also, in the above-mentioned embodiment, a constitution provided with a motor as a driving means of a present invention was described.

[0106] However, the present invention is not limited thereto, and it is possible to use an engine, such as a diesel engine, or a turbine, such as a steam turbine, as the driving means of the present invention. In such a case, it is possible to acquire the demand amount of gas of the demand end device by detecting the engine or turbine torque in place of the flow rate detector 6.

[0107] Also, in the aforementioned embodiment, the constitution was described in which the rotational frequency of the motor 23 is constant. However, the present invention is not limited thereto, and for example the rotational frequency of the motor 23 may be changed in accordance with the intake amount of gas of the gas compression portion 2. In such a case, an inverter motor is often used as the motor 23.

[0108] Also, in the aforementioned embodiment, the constitution was described in which the diffusers 21h and 22h are disposed just after the impellers 21a and 22a, respectively, and the gas is circulated and supplied to the diffusers 21h and 22h.

[0109] However, the present invention is not limited thereto, and for example, in the case of a throttle channel or the like existing between the impeller 21a and 22a and the diffuser 21h and 22h, it is possible to circulate and supply gas to the diffusers 21h and 22h, or between the diffusers 21h and 22h and the impellers 21a and 22a (that is, the throttle channel).

[0110] Also, the present invention can be applied to a multi-stage compressor with a single shaft and multiple stages, in which a plurality of centrifugal compressors are disposed in multiple stages on a single shaft, and a multi-stage compressor with multiple shafts and multiple stages, in which a centrifugal compressor is disposed on each shaft of the plurality of shafts via a gear type speed increasing mechanism.

[0111] Also, as the gas of the present invention, for example it is possible to use air, nitrogen, oxygen, or carbon dioxide gas.

INDUSTRIAL APPLICABILITY

[0112] According to the gas compression device and a method of controlling the gas compression device of the present invention, while suppressing the occurrence of surging in a centrifugal compressor, it is possible to sufficiently reduce the load of a motor, and it is possible to reduce the consumption of energy.

Claims

1. A gas compression device that arranges a plurality of compression means provided with impellers that impart velocity energy to a gas, and a diffuser that converts the velocity energy to pressure energy in series in the flow direction of gas and supplies the gas that is compressed via the plurality of the compression means to a predetermined demand end, comprising:

   a drive means that supplies power to the impeller;
   a flow rate adjusting means that adjusts the flow rate of the gas that is drawn into the compression means that is positioned furthest upstream with respect to the flow direction of the gas;
   a circulation and supply means that is capable of circulating and supplying at least a portion of the gas that is discharged from the compression means that is positioned furthest downstream with respect to the flow direction of the gas to the diffuser or is positioned between the diffuser and the impeller of each compression means, and
   a control means that controls at least the drive means, the flow rate adjusting means, and the circulation and supply means;
   wherein, the control means
   controls the flow rate adjusting means in accordance with a demand amount of the gas of the demand end, and
   in each compression means, in the case of the flow rate of the gas that is drawn in falling below a set value that is set based on a surging limit in the compression means, controls the circulation and supply means to circulate and supply a portion of the gas in the compression means.

2. The gas compression device according to claim 1, provided with a pressure detecting means that detects the pressure of the gas that is discharged from the compression means that is positioned furthest downstream, and a flow rate detecting means that detects the flow rate of the gas that is discharged from the compression means that is positioned furthest downstream,
   wherein, the control means performs control of the flow rate adjusting means with at least the detection result of the pressure detecting means serving as the demand amount of the gas of the demand end, among the pressure detecting means and the flow rate detecting means.

3. The gas compression device according to claim 1, wherein the control means starts circulation and supply of the gas by the circulation and supply means in stages from the compression means that is positioned furthest downstream toward the upstream compression means.

4. The gas compression device according to claim 1, wherein the set value is a value that matches the flow rate of the surging limit in the compression means and a predetermined margin.

5. The gas compression device according to claim 1, wherein the control means, in the case of the demand amount of the gas of the demand end being zero, maintains the intake of the gas in the compression means that is positioned furthest upstream with respect to the flow direction of the gas, and exhausts a portion of the gas that is discharged from the compression means that is positioned furthest downstream with respect to the flow direction of the gas without supplying it to the demand end.

6. A method of controlling a gas compression device that arranges a plurality of compression means provided with an impeller that imparts velocity energy to a gas and a diffuser that converts the velocity energy to pressure energy in series in the flow direction of gas, and supplies the gas that is compressed via the plurality of the compression means to a predetermined demand end, comprising the steps of:

   adjusting the flow rate of gas that is drawn into the compression means that is positioned furthest upstream with respect to the flow direction of the gas in accordance with a demand amount of the gas of the demand end, and
   in each compression means, circulating and supplying at least a portion of the gas that is discharged from the compression means that is positioned furthest downstream with respect to

the flow direction of the gas to the diffuser or between the diffuser and the impeller of each compression means in the case of the flow rate of the gas that is drawn in falling below a set value that is set based on a surging limit in the compression means.

7. The method of controlling a gas compression device according to claim 6, **characterized by** detecting the pressure and the flow rate of the gas that is discharged from the compression means that is positioned furthest downstream and, among this detection result, controlling the flow rate of the gas that is drawn into the compression means that is positioned furthest upstream with at least the pressure serving as the demand amount of the gas at the demand end.

8. The method of controlling a gas compression device according to claim 6, **characterized by** starting the circulation and supply of the gas in stages from the compression means that is positioned furthest downstream toward the upstream compression means.

9. The method of controlling a gas compression device according to claim 6, **characterized by** the set value being a value that matches the flow rate of the surging limit in the compression means and a predetermined margin.

10. The method of controlling a gas compression device according to claim 6, **characterized by**, in the case of the demand amount of the gas at the demand end being zero, maintaining the intake of the gas in the compression means that is positioned furthest upstream with respect to the flow direction of the gas, and exhausting a portion of the gas that is discharged from the compression means that is positioned furthest downstream with respect to the flow direction of the gas without supplying it to the demand end.

FIG. 1

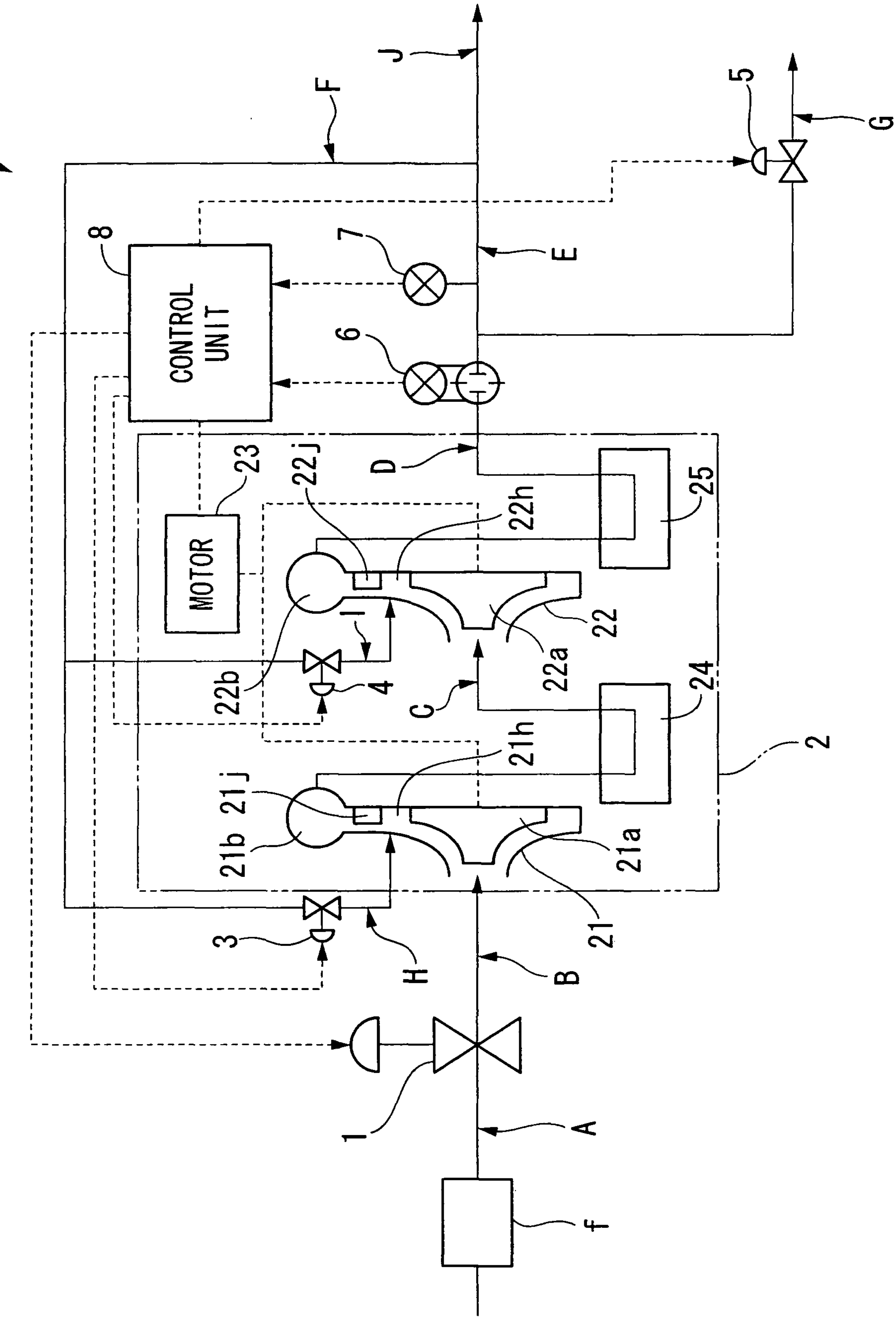

S
F
J
5
G
8
CONTROL UNIT
7
E
6
23
MOTOR
22j
D
22h
25
22b
I
4
22
22a
C
24
21h
21j
21b
21a
2
3
H
B
21
1
A
f

FIG. 2

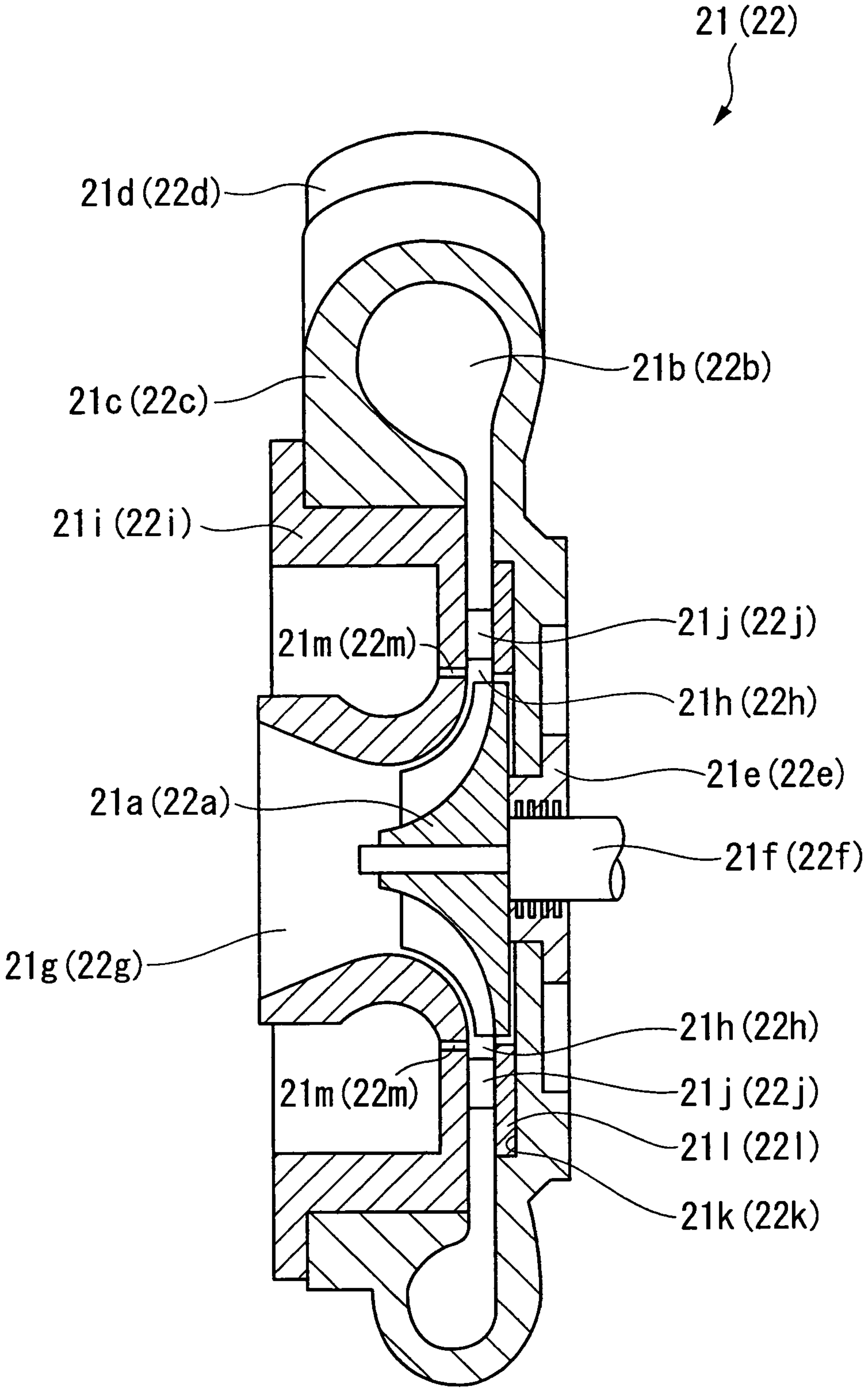

21 (22)
21d (22d)
21b (22b)
21c (22c)
21i (22i)
21j (22j)
21m (22m)
21h (22h)
21e (22e)
21a (22a)
21f (22f)
21g (22g)
21h (22h)
21j (22j)
21m (22m)
21l (22l)
21k (22k)

FIG. 3

A (FLOW RATE %)	B (FLOW RATE %)	C (FLOW RATE %)	D (FLOW RATE %)	E (FLOW RATE %)	F (FLOW RATE %)	G (FLOW RATE %)	H (FLOW RATE %)	I (FLOW RATE %)	J (FLOW RATE %) (DEMAND FLOW RATE)
100	100	100	100	100	0	0	0	0	100
70	70	70	70	70	0	0	0	0	70
60	60	60	70	70	10	0	0	10	60
50	50	60	70	70	20	0	10	10	50
10	10	60	70	70	60	0	50	10	10
10	10	60	70	60	60	10	50	10	0

FIG. 4

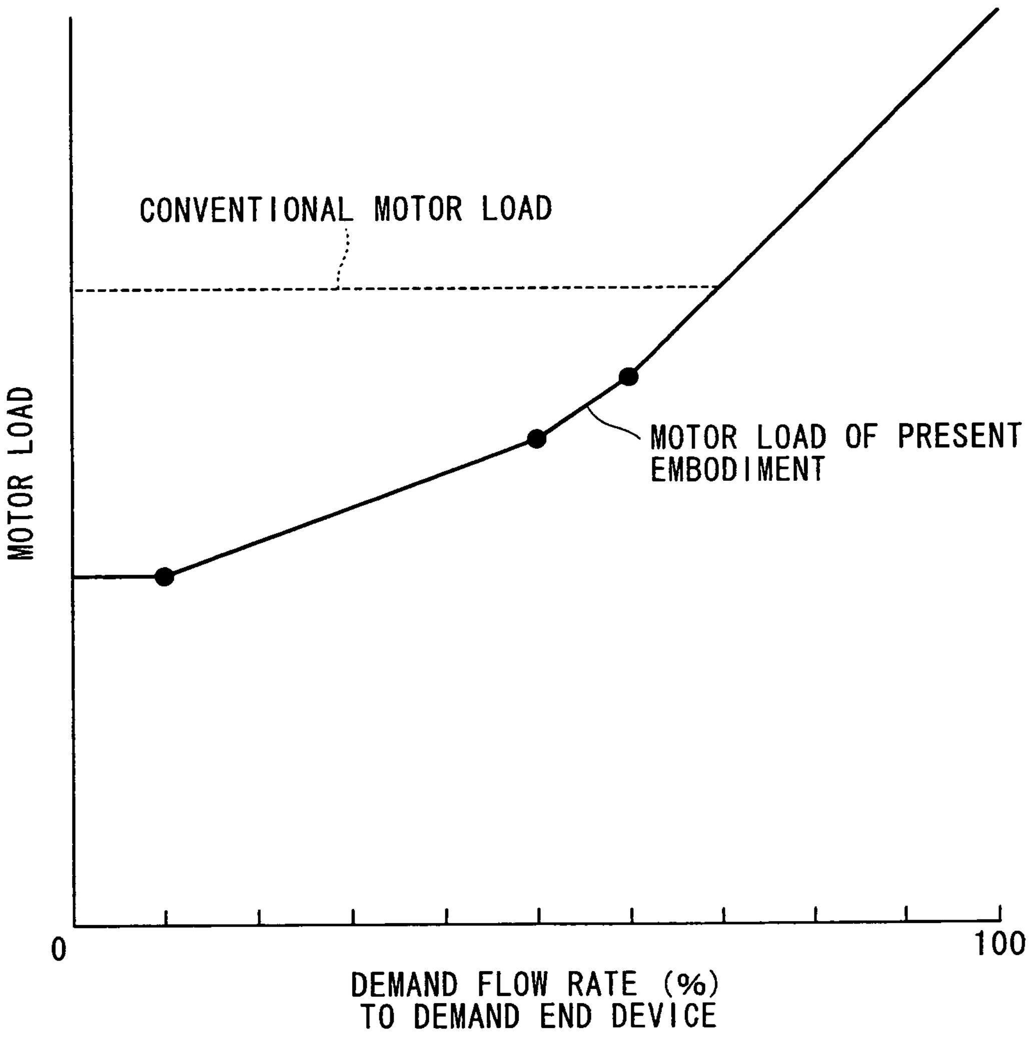

CONVENTIONAL MOTOR LOAD
MOTOR LOAD
MOTOR LOAD OF PRESENT EMBODIMENT
0
100
DEMAND FLOW RATE (%) TO DEMAND END DEVICE

FIG. 5

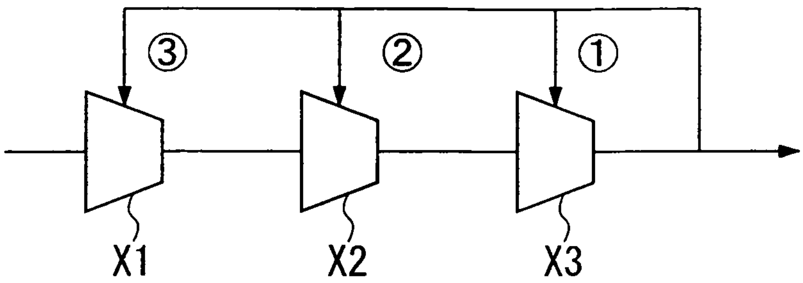


FIG. 6

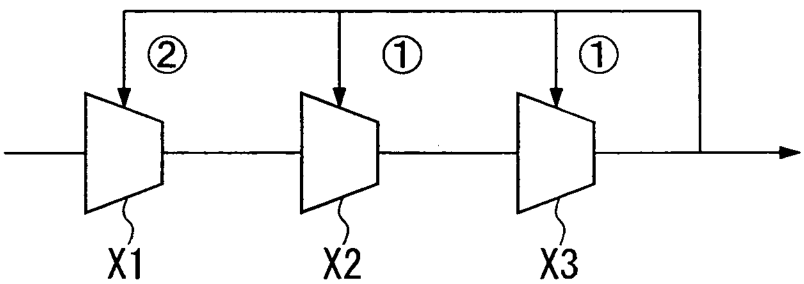
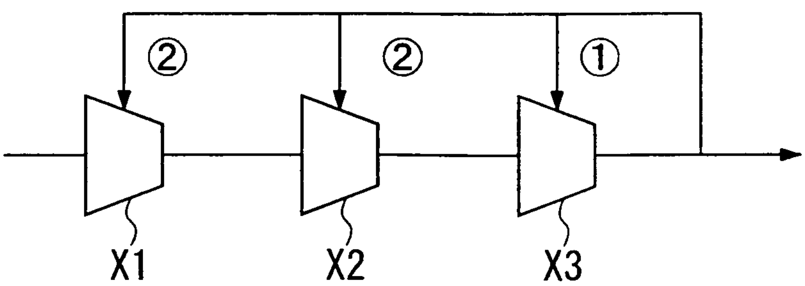


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/062268

A. CLASSIFICATION OF SUBJECT MATTER
F04D27/02(2006.01)i, *F04D17/12*(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)
F04D27/02, F04D17/12

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2-259298 A (Ishikawajima-Harima Heavy Industries Co., Ltd.), 22 October, 1990 (22.10.90), Page 2, upper right column, line 20 to page 3, lower left column, line 8; Fig. 1 (Family: none)	1-4,6-9 5,10
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 133757/1988(Laid-open No. 54400/1990) (Kobe Steel, Ltd.), 19 April, 1990 (19.04.90), Page 4, line 10 to page 6, line 17; Figs. 1 to 3 (Family: none)	1-4,6-9

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 September, 2008 (22.09.08)	07 October, 2008 (07.10.08)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/062268

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 8-284892 A (Mitsubishi Heavy Industries, Ltd.), 29 October, 1996 (29.10.96), Par. Nos. [0015] to [0022]; Fig. 1 (Family: none)	1-4,6-9
Y	JP 10-252696 A (Ishikawajima-Harima Heavy Industries Co., Ltd.), 22 September, 1998 (22.09.98), Par. Nos. [0020] to [0023]; Fig. 1 (Family: none)	2,7
Y	JP 2005-16464 A (Ishikawajima-Harima Heavy Industries Co., Ltd.), 20 January, 2005 (20.01.05), Par. No. [0008] (Family: none)	4,9

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REFERENCES CITED IN THE DESCRIPTION

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