COMBUSTION SYSTEM, EXHAUST GAS COMBUSTION CONTROL METHOD AND APPARATUS, ELECTRONIC DEVICE, AND COMPUTER-READABLE STORAGE MEDIUM

CROSS-REFERENCE TO THE RELATED APPLICATIONS

[0001] The present disclosure claims priority to Chinese Patent Application No. 202412000062.9, filed with the China National Intellectual Property Administration on December 31, 2024, and entitled "COMBUSTION SYSTEM, EXHAUST GAS COMBUSTION CONTROL METHOD AND APPARATUS, ELECTRONIC DEVICE, AND COMPUTER-READABLE STORAGE MEDIUM", the contents of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to the technical field of exhaust gas treatment, and specifically to a combustion system, an exhaust gas combustion control method, an exhaust gas combustion control apparatus, an electronic device, and a computer-readable storage medium.

BACKGROUND

[0003] With the continuous development of industrial production, exhaust gas treatment has become an important part of environmental protection. Among related exhaust gas treatment methods, the combustion method is widely used due to its high efficiency and simple operation. The basic principle of the combustion method is to decompose harmful gases into harmless substances at high temperatures, so as to achieve the objective of purifying exhaust gas.

[0004] However, the inventors have found through research that during combustion, combustible components in exhaust gas undergo intense reactions at high temperatures, leading to a sharp rise in pressure inside the furnace. Such a pressure rise phenomenon not only affects combustion efficiency, but also may cause equipment damage and even explosion accidents.

SUMMARY

[0005] Objectives of the present disclosure include providing a combustion system, an exhaust gas combustion control method, an exhaust gas combustion control apparatus, an electronic device, and a computer-readable storage medium, so as to ensure thorough combustion and purification of exhaust gas and prevent deflagration risk.

[0006] The combustion system includes a reaction chamber, an exhaust fan, a first control valve, a second control valve, and a first pressure sensor. Herein, the reaction chamber is provided with an inlet configured to introduce an exhaust gas and an outlet configured to discharge the exhaust gas, and the exhaust fan is disposed adjacent to the outlet of the reaction chamber. On the basis of the above, from the inlet to the outlet, the reaction chamber includes therein a first combustion zone on the inlet side and a second combustion zone on the outlet side. Correspondingly, the reaction chamber is further provided with a first air supplement port and a second air supplement port, and compressed air is introduced into the first combustion zone and the second combustion zone through the first air supplement port and the second air supplement port, respectively, so as to react with the exhaust gas in sequence, achieving staged combustion. To facilitate control of a flow rate of the introduced compressed air and maintain a pressure in an inner cavity of the reaction chamber in a stable state at all times, the first control valve and the second control valve are respectively provided on air supply pipelines communicating with the first air supplement port and the second air supplement port.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] To more clearly illustrate the technical solutions of embodiments of the present disclosure, the drawings that need to be used in the embodiments will be briefly described below. It should be understood that the following drawings only show some embodiments of the present disclosure and thus should not be regarded as limiting the scope. For those of ordinary skill in the art, other related drawings still can be obtained in light of these drawings without making inventive efforts.

[0008] FIG. 1 is a first structural schematic diagram of a combustion system provided in the present embodiment;

[0009] FIG. 2 is a second structural schematic diagram of the combustion system provided in the present embodiment;

[0010] FIG. 3 is a third structural schematic diagram of the combustion system provided in the present embodiment;

[0011] FIG. 4 is a fourth structural schematic diagram of the combustion system provided in the present embodiment;

[0012] FIG. 5 is a sectional structural schematic diagram taken along A-A in FIG. 4 provided in the present embodiment;

[0013] FIG. 6 is a fifth structural schematic diagram of the combustion system provided in the present embodiment;

[0014] FIG. 7 is a sectional structural schematic diagram taken along B-B in FIG. 6 provided in the present embodiment;

[0015] FIG. 8 is another sectional structural schematic diagram taken along B-B in FIG. 6 provided in the present embodiment;

[0016] FIG. 9 is a schematic flow block diagram of an exhaust gas combustion control method provided in the present embodiment;

[0017] FIG. 10 is a structural schematic block diagram of an exhaust gas combustion control apparatus provided in the present embodiment;

[0018] FIG. 11 is a structural schematic block diagram of an electronic device provided in the present embodiment.

[0019] Reference signs: 10 - combustion system; 20 - electronic device; 21 - memory; 23 - processor; 30 - exhaust gas combustion control apparatus; 31 - acquisition module; 33 - first control module; 35 - second control module; 100 - reaction chamber; 101 - inlet; 102 - outlet; 103 - first air supplement port; 104 - second air supplement port; 105 - third air supplement port; 106 - fourth air supplement port; 110 - inner cylinder; 111 - third water port; 113 - fourth water port; 120 - first water-cooling cavity; 130 - outer cylinder; 131 - first water port; 133 - second water port; 151 - first channel; 153 - second channel; 210 - first combustion zone; 230 - second combustion zone; 250 - third combustion zone; 300 - partition plate; 310 - second water-cooling cavity; 400 - pressure relief pipe; 500 - exhaust fan; 610 - first control valve; 630 - second control valve; 650 - third control valve; 710 - first pressure sensor; 730 - second pressure sensor; 750 - third pressure sensor.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0020] In the related art, exhaust gas purification solutions that decompose harmful gases into harmless substances through combustion have problems of violent reaction, sharp rise in furnace pressure, and explosion accidents.

[0021] In view of the above problems, the present disclosure provides a combustion system, an exhaust gas combustion control method, an exhaust gas combustion control apparatus, an electronic device 20, and a storage medium, which adopt a staged combustion solution so as to maintain a pressure in an inner cavity of the reaction chamber 100 in a stable state at all times, ensuring that the exhaust gas can be subjected to stable combustion treatment.

[0022] To make the objectives, technical solutions, and advantages of embodiments of the present disclosure clearer, the technical solutions in embodiments of the present disclosure will be clearly and completely described below with reference to the drawings in the embodiments of

the present disclosure. Obviously, only some but not all embodiments of the present disclosure are described. Components in the embodiments of the present disclosure generally described and shown in the drawings herein may be arranged and designed in various different configurations.

[0023] Therefore, the following detailed description of the embodiments of the present disclosure provided in the drawings is not intended to limit the scope of the present disclosure as claimed, but merely represents selected embodiments of the present disclosure. Based on embodiments of the present disclosure, all other embodiments obtained by those of ordinary skill in the art without making inventive efforts shall fall within the protection scope of the present disclosure.

[0024] It should be noted that similar reference signs and letters denote similar items in the following drawings. Therefore, once an item is defined in one drawing, it does not need to be further defined or explained in subsequent drawings.

[0025] In the description of the present disclosure, it should be noted that orientation or positional relationship indicated by the terms such as “upper”, “lower”, “inner”, and “outer”, if appear, are based on the orientation or positional relationship shown in the drawings, or the orientation or positional relationship conventionally placed when the product of the invention is used. They are only for the convenience of describing the present disclosure and simplifying the description, rather than indicating or implying that the referred device or element must have a specific orientation, be constructed and operated in a specific orientation, and thus should not be construed as limiting the present disclosure.

[0026] In addition, the terms such as “first” and “second”, if appear, are used only for distinguishing descriptions, and they should not be construed as indicating or implying relative importance.

[0027] It should be noted that features in the embodiments of the present disclosure may be combined with each other without conflict.

[0028] FIG. 1 is a first structural schematic diagram of a combustion system 10 provided in the present embodiment, and the direction indicated by arrows in FIG. 1 is a flow direction of an exhaust gas. Referring to FIG. 1, the present disclosure provides the combustion system 10 applied to the technical field of exhaust gas treatment, which includes a reaction chamber 100, an exhaust fan 500, a first control valve 610, a second control valve 630, and a first pressure sensor 710.

[0029] Herein, the reaction chamber 100 is provided with an inlet 101 configured to introduce the exhaust gas and an outlet 102 configured to discharge the exhaust gas, and the exhaust fan 500 is disposed adjacent to the outlet 102 of the reaction chamber 100. In practical application

scenarios, the exhaust fan 500 can reduce an air pressure inside the reaction chamber 100 by discharging a gas from the reaction chamber 100, forming a negative pressure zone. Based on the above pressure difference configuration, the exhaust gas outside the reaction chamber 100 can be promoted to flow into the reaction chamber 100 through the inlet 101, and after being combusted and treated inside the reaction chamber, is discharged through the outlet 102. In addition, it should be supplemented that in embodiments provided by the present disclosure, the introduced exhaust gas may be high-flow hydrogen or other highly flammable and explosive gases.

[0030] On the basis of the above, from the inlet 101 to the outlet 102, the reaction chamber 100 includes therein a first combustion zone 210 on the inlet 101 side and a second combustion zone 230 on the outlet 102 side. Correspondingly, the reaction chamber 100 is further provided with a first air supplement port 103 and a second air supplement port 104, which are disposed corresponding to the first combustion zone 210 and the second combustion zone 230, respectively. Based on this, compressed air is introduced into the first combustion zone 210 and the second combustion zone 230 through the first air supplement port 103 and the second air supplement port 104, respectively, so as to react with the exhaust gas in sequence, achieving staged combustion.

[0031] To facilitate control of a flow rate of the introduced compressed air and maintain the pressure in an inner cavity of the reaction chamber 100 in a stable state at all times, the first control valve 610 and the second control valve 630 are respectively provided on air supply pipelines communicating with the first air supplement port 103 and the second air supplement port 104. In addition, since the first combustion zone 210 is disposed adjacent to the inlet 101 and is in an environment with high temperature and high-concentration exhaust gas, the reaction between the introduced compressed air and the exhaust gas is a main reaction, with significant pressure fluctuation. Therefore, the first pressure sensor 710 is disposed in the first combustion zone 210 and configured to acquire a first pressure value of the first combustion zone 210 inside the reaction chamber 100.

[0032] In practical scenarios, on the basis of staged combustion in the first combustion zone 210 and the second combustion zone 230, considering that the reaction in the first combustion zone 210 is the main reaction, if the first pressure value indicates a possible deflagration risk in the first combustion zone 210, an operator can reduce an opening of the first control valve 610, decrease a supplement amount of the compressed air, reduce a reaction amount of the exhaust gas, and lower the pressure in the reaction chamber 100. If the first pressure value indicates that the first combustion zone 210 is in a stable state and there is not deflagration risk of the exhaust

gas, the supply of the compressed air can be continued on the basis of the relevant opening of the first control valve 610.

[0033] In addition, since the second control valve 630 is disposed adjacent to the outlet 102, the second control valve 630 is normally in an open state to maintain oxygen-enriched introduction, so as to achieve the purpose of completely treating the exhaust gas and diluting the exhaust gas to below a limit value. Correspondingly, a second pressure sensor 730 may also be disposed at the outlet 102 of the reaction chamber 100, i.e., the second combustion zone 230, so as to facilitate real-time acquisition of pressure changes inside the second combustion zone 230, ensuring that the combustion treatment or dilution treatment at the outlet 102 proceeds normally.

[0034] Referring again to FIG. 1, to realize the staged combustion, the reaction chamber 100 further includes therein a third combustion zone 250 located between the first combustion zone 210 and the second combustion zone 230. Moreover, the reaction chamber 100 is further provided with a third air supplement port 105 corresponding to the third combustion zone 250. The third air supplement port 105, similar to the air supplement ports in the foregoing embodiments, is also configured to introduce compressed air into the third combustion zone 250. Correspondingly, the combustion system 10 further includes a third control valve 650, where the third control valve 650 is disposed on an air supply pipeline communicating with the third air supplement port 105, so as to facilitate controlling the flow rate of the compressed air introduced into the third combustion zone 250.

[0035] It should be supplemented that since the third combustion zone 250 is located between the first combustion zone 210 and the second combustion zone 230, in the third combustion zone 250, the intensity of reaction between the compressed air introduced by the third control valve 650 and the exhaust gas is weaker than that in the first combustion zone 210 and stronger than that in the second combustion zone 230. The pressure fluctuation is relatively significant, and there is also a deflagration risk. Based on this, the combustion system 10 further includes a third pressure sensor 750. The third pressure sensor 750 is configured to acquire a second pressure value of the third combustion zone 250 inside the reaction chamber 100. It is easy to understand that the exhaust gas realizes small-scale local combustion, small-scale local combustion, and complete treatment and dilution to below a limit value in the first combustion zone 210, the third combustion zone 250, and the second combustion zone 230, respectively.

[0036] Based on the above, the addition of the third air supplement port 105 and the third control valve 650 controls a mixing ratio of the exhaust gas to the compressed air and a combustion rate, reduces the pressure and temperature at a single air supplement port (the first air supplement port 103/the second air supplement port 104), lowers the deflagration risk of the

reaction chamber 100, and achieves the staged combustion. In some other embodiments, to realize safer, more efficient, and more environmentally friendly staged combustion, the third combustion zone 250 may further include a plurality of sub-combustion zones arranged in sequence along the flow direction of the exhaust gas. Correspondingly, the reaction chamber 100 may further be provided with a plurality of sub-air supplement ports respectively configured to introduce the compressed air into the plurality of sub-combustion zones. Correspondingly, the combustion system 10 may further include a plurality of regulating valves configured to respectively regulate an introduction amount of the compressed air introduced into the plurality of sub-combustion zones through the plurality of sub-air supplement ports. Optionally, any control valve before the second control valve 630 is a control valve with an adjustable opening.

[0037] Referring to FIGS. 2 to 8, the present disclosure further provides another embodiment of the combustion system 10, which differs from the embodiment provided in FIG. 1 in that the combustion system 10 further includes a partition plate 300 located inside the reaction chamber 100. In this embodiment, the inlet 101 and the outlet 102 are located on two sides of the partition plate 300, respectively, and correspondingly, the first air supplement port 103 and the second air supplement port 104 are also located on two sides of the partition plate 300, respectively. Moreover, the partition plate 300 mates with an inner wall of the reaction chamber 100 to form a U-shaped channel configured to guide the exhaust gas, so that the exhaust gas introduced from the inlet 101 flows around the partition plate 300 and then is discharged from the outlet 102. In this process, a circuitous gas flow path increases the residence time of the exhaust gas in the reaction chamber 100, allowing the reaction to proceed more thoroughly, and achieving higher exhaust gas treatment efficiency. Similar to the foregoing, the compressed air introduced through the first air supplement port 103 and the second air supplement port 104 still reacts with the exhaust gas in sequence, realizing the staged combustion.

[0038] As shown in FIGS. 4 and 5, to increase the flow path and residence time of the exhaust gas in the reaction chamber 100, the U-shaped channel is arranged upside down, i.e., a bottom wall of the reaction chamber 100 is provided with the inlet 101 and the outlet 102, and there is a gap between a top wall of the reaction chamber 100 and the partition plate 300. Based on this, the exhaust gas enters from the inlet 101 on the bottom wall, rises from bottom to top on one side of the partition plate 300, reaches the top wall, crosses to the other side of the partition plate 300 through the gap between the partition plate 300 and the top wall, and then is discharged from top to bottom. It is easy to understand that in this embodiment, the first combustion zone 210 and the second combustion zone 230 are located on two sides of the partition plate 300, respectively, and the third combustion zone 250 is at least partially located at the gap.

[0039] As mentioned in the preceding, the first combustion zone 210 and the third combustion zone 250 are a main reaction zone and a secondary reaction zone, respectively. To improve the reaction uniformity of the exhaust gas and avoid local excessive reaction, the number of the first air supplement ports 103 is plural, and the plurality of first air supplement ports 103 are arranged at intervals along a circumferential direction of the reaction chamber 100. Correspondingly, the number of the third air supplement ports 105 is also plural, and the plurality of third air supplement ports 105 are arranged at intervals along the circumferential direction of the reaction chamber 100.

[0040] It should also be supplemented that in cases where the number of the third air supplement ports 105 is plural, they may be arranged at equal intervals along the circumferential direction of the entire reaction chamber 100 so as to uniformly act on the exhaust gas flowing through the gap; in cases where the number of the first air supplement ports 103 is plural, they may be arranged at equal intervals on one side of the inlet 101 of the reaction chamber 100 so as to uniformly act on the exhaust gas passing through the inlet 101. In addition, to improve the oxygen enrichment degree in the second zone, as shown in FIG. 5, fourth air supplement ports 106 may also be arranged at equal intervals on one side of the outlet 102 of the reaction chamber 100. Optionally, the compressed air through the first air supplement ports 103 and the fourth air supplement ports 106 is switched on and off via the same control valve.

[0041] Considering that the exhaust gas releases a great amount of heat during reaction, referring again to FIG. 4, the reaction chamber 100 includes an inner cylinder 110 and an outer cylinder 130. Herein, an inner cavity of the inner cylinder 110 is a combustion cavity configured to receive the exhaust gas and compressed air for combustion reaction. The outer cylinder 130 and the inner cylinder 110 together form a double-layer structure, and a first water-cooling cavity 120 is formed between an inner wall of the outer cylinder 130 and an outer wall of the inner cylinder 110. It is easy to understand that cooling water in the first water-cooling cavity 120 can effectively absorb high-temperature heat generated in the combustion cavity, ensuring that a temperature of the reaction chamber 100 is controllable.

[0042] In some embodiments, to facilitate recovery and utilization of the above high-temperature heat, the cooling water in the first water-cooling cavity 120 may be circulating water. As shown in FIG. 3, the outer cylinder 130 is provided with a first water port 131 and a second water port 133 at intervals along a vertical direction. It is easy to understand that cooling water is introduced into the first water-cooling cavity 120 through one of the first water port 131 and the second water port 133, and the cooling water in the first water-cooling cavity 120 is discharged through the other of the first water port 131 and the second water port 133.

[0043] Exemplarily, in cases where the first water port 131 is located below the second water port 133 as shown in FIG. 3, after circulating water enters the first water-cooling cavity 120 through the first water port 131, it flows from bottom to top to ensure full contact with and absorption of heat released from the inner wall of the combustion cavity, so as to maximize heat exchange efficiency. In addition, it also should be supplemented that in cases where a water source is a circulating water tank, both the first water port 131 and the second water port 133 communicate with the water source; in cases where the water source is PCW, one of the first water port 131 and the second water port 133 communicates with the water source, and the other communicates with a heat supply pipeline, serving as a heat source for other processes, thereby improving energy utilization efficiency.

[0044] Correspondingly, referring to FIGS. 6 to 8, to prevent the partition plate 300 from being burnt out by high temperature, the partition plate 300 is of a hollow structure, and an inner cavity of the partition plate 300 is a second water-cooling cavity 310. It is easy to understand that the existence of the second water-cooling cavity 310 ensures that a temperature of the partition plate 300 is always within a safe range, prolonging the service life of the partition plate 300.

[0045] In addition, in some embodiments, as shown in FIG. 7, a third water port 111 and a fourth water port 113 are arranged at intervals at a joint between the inner cylinder 110 and the partition plate 300 in the vertical direction. Moreover, the second water-cooling cavity 310 communicates with the first water-cooling cavity 120 through the third water port 111 and the fourth water port 113. Based on this, the first water-cooling cavity 120 and the second water-cooling cavity 310 communicate in common circulation, forming a multi-level cooling system, improving the overall thermal management efficiency, and ensuring more uniform temperature distribution of all parts inside the reaction chamber 100.

[0046] In some embodiments, as shown in FIG. 8, the reaction chamber 100 is provided with a first channel 151 and a second channel 153 that penetrate the outer cylinder 130 and the inner cylinder 110 and communicate with the second water-cooling cavity 310. Based on this, the second water-cooling cavity 310, similar to the first water-cooling cavity 120, can directly communicate with the heat supply pipeline through the first channel 151 or the second channel 153, serving as a heat source for other processes, thereby improving energy utilization efficiency. To maximize heat exchange efficiency, channel structures are also similar to the foregoing water ports, i.e., the first channel 151 and the second channel 153 are arranged at intervals along the vertical direction, cooling water is introduced into the second water-cooling cavity 310 through one of the first channel 151 and the second channel 153, and the cooling water in the second

water-cooling cavity 310 is discharged through the other of the first channel 151 and the second channel 153.

[0047] To avoid occurrence of explosion accidents, the combustion system 10 further includes a pressure relief pipe 400 communicating with the inner cavity of the reaction chamber 100. The pressure relief pipe 400 is provided therein with a one-way pressure relief device operated by pressure control as a protection measure, so as to relieve high pressure caused by high-energy deflagration inside the reaction chamber 100 to the atmospheric environment. Optionally, a fourth pressure sensor, a rupture disc (pressure relief diaphragm), and a limit switch are provided in the pressure relief pipe 400. The fourth pressure sensor is configured to acquire instantaneous pressure fluctuation in the pressure relief pipe 400. The limit switch is in communication connection with the fourth pressure sensor and configured to open or close the rupture disc so as to connect the inner cavity of the reaction chamber 100 with the external environment or disconnect the inner cavity of the reaction chamber 100 from the external environment.

[0048] In practical scenarios, in cases where the fourth pressure sensor detects that the instantaneous pressure fluctuation in the pressure relief pipe 400 is greater than a set value, it is determined that the instantaneous pressure fluctuation inside the reaction chamber 100 is too large. At this time, the fourth pressure sensor transmits a signal to the limit switch, triggering the limit switch to release the limit effect on the rupture disc, so that the rupture disc is opened, thereby directly relieving high pressure caused by high-energy deflagration to the atmospheric environment. Optionally, the rupture disc is an aluminum disc.

[0049] Referring to FIG. 9, an embodiment of the present disclosure further provides an exhaust gas combustion control method applied to the combustion system 10 of the foregoing embodiments. The exhaust gas combustion control method may include the following steps.

[0050] Step S100: controlling, in response to introduction of an exhaust gas into the reaction chamber 100, the exhaust fan 500, the first control valve 610, and the second control valve 630 to open.

[0051] Before step S100, the exhaust gas can be introduced into a pre-water-washing device to remove water-soluble gases or dust and then introduced into the reaction chamber 100.

[0052] In step S100, it should be noted that opening of the first control valve 610 and the second control valve 630 can realize continuous introduction of compressed air, ensuring that during the passage of the exhaust gas through the reaction chamber 100, a steady stream of compressed air reacts with the exhaust gas, so as to ensure that the exhaust gas is combusted thoroughly and purified efficiently. The exhaust fan 500 is configured to drive the exhaust gas

into the reaction chamber 100 for combustion and decomposition, flow in a direction from the inlet 101 to the outlet 102, and finally be discharged out of the reaction chamber 100.

[0053] Step S200: acquiring a first pressure value inside the reaction chamber 100.

[0054] In step S200, the first pressure value is based on a measured value of the first pressure sensor 710, and the first pressure sensor 710 is located in the first combustion zone 210. Considering that the pressure fluctuation at the inlet 101 of the reaction chamber 100 is significant, optionally, the first pressure sensor 710 is located on a side of the first combustion zone 210 close to the inlet 101.

[0055] Step S300: controlling, in response to a difference between the first pressure value and a first preset pressure value being greater than a first preset range, to reduce an opening of the first control valve 610.

[0056] In step S300, by determining whether the difference between the first pressure value and the first preset pressure value is within the first preset range, whether the pressure inside the reaction chamber 100 is in a relatively stable state can be confirmed. If the difference between the first pressure value and the first preset pressure value is greater than the first preset range, it indicates that the pressure in the reaction chamber 100 at this time is in an unstable state, and there is a risk of deflagration of the exhaust gas. Based on this, the opening of the first control valve 610 is reduced, decreasing a supplement amount of the compressed air, and reducing a reaction amount of the exhaust gas, i.e., oxygen-deficient combustion, thereby achieving the beneficial effects of lowering the pressure in the reaction chamber 100, maintaining a stable pressure inside the reaction chamber 100, and preventing the deflagration risk.

[0057] Correspondingly, if the difference between the first pressure value and the first preset pressure value is less than or equal to the first preset range, it indicates that the pressure in the reaction chamber 100 at this time is in a stable state, there is no risk of deflagration of the exhaust gas, and the compressed air can be continuously introduced on the basis of the relevant opening of the first control valve 610.

[0058] It should be noted that based on the mechanism of feedback adjusting the opening of the first control valve 610 according to the first pressure value inside the reaction chamber 100, a PID (Proportional-Integral-Derivative) control algorithm can be used to adjust a valve opening. Optionally, the preset range can be set according to ten percent of the first preset pressure value.

[0059] Based on the above, taking the first preset pressure value as P for example, in cases where the exhaust gas is introduced into the reaction chamber 100, in the first combustion zone 210, the compressed air is introduced through the first control valve 610 to preferentially treat a small amount of local exhaust gas. At this time, a pressure value in the first combustion zone 210

is allowed to fluctuate within a range of less than or equal to P+10%P. If the first pressure sensor 710 detects that the first pressure value is greater than the range of P+10%P, it indicates that the pressure fluctuation in the first combustion zone 210 increases at this time. In this case, the opening of the first control valve 610 is reduced, decreasing the supplement amount of the compressed air, reducing the reaction amount of the exhaust gas, lowering the pressure of the reaction chamber 100, maintaining the stable pressure inside the reaction chamber 100, and preventing the deflagration risk.

[0060] Referring again to FIG. 9, the exhaust gas combustion control method provided by the present disclosure further includes the following steps.

[0061] Step S400: acquiring a second pressure value inside the reaction chamber 100.

[0062] In step S400, the second pressure value is based on a measured value of a third pressure sensor 750, and the third pressure sensor 750 is located in the third combustion zone 250. Considering that the pressure fluctuation in the first combustion zone 210 is significant, optionally, the third pressure sensor 750 is located on a side of the third combustion zone 250 close to the first combustion zone 210.

[0063] Step S500: controlling, in response to a difference between the second pressure value and a second preset pressure value being greater than a second preset range, to reduce an opening of the third control valve 650.

[0064] In step S500, similar to the foregoing, by determining whether the difference between the second pressure value and the second preset pressure value is within the second preset range, whether the pressure inside the third combustion zone 250 is in a relatively stable state can be confirmed. If the difference between the second pressure value and the second preset pressure value is greater than the second preset range, it indicates that the pressure inside the third combustion zone 250 is in an unstable state at this time, and there is a risk of deflagration of the exhaust gas. Based on this, the opening of the third control valve 650 is reduced, which helps to decrease the supplement amount of compressed air herein and reduce the reaction amount of exhaust gas herein, thereby achieving the beneficial effects of lowering the pressure in the third combustion zone 250, maintaining the stable pressure inside the third combustion zone 250, and preventing the deflagration risk.

[0065] Correspondingly, if the difference between the second pressure value and the second preset pressure value is less than or equal to the second preset range, it indicates that the pressure in the third combustion zone 250 is in a stable state at this time, and there is no risk of deflagration of the exhaust gas. The compressed air can be continuously introduced on the basis of the relevant opening of the third control valve 650.

[0066] In addition, it should be supplemented that the execution order of the above steps S200 to S300 and the above steps S400 to S500 does not affect the final result. That is, steps S200 to S300 and steps S400 to S500 can be performed in a non-linear manner (simultaneously), rather than necessarily following a strict sequential order.

[0067] It should be noted that, similar to the foregoing, based on the mechanism of feedback adjusting the opening of the third control valve 650 according to the second pressure value inside the reaction chamber 100, the PID control algorithm can also be used to adjust the opening of the third control valve 650. In addition, it also should be noted that in embodiments where more than three control valves are provided, any control valve before the second control valve 630 is a control valve with an adjustable opening. The opening of the control valve is adjusted based on a control algorithm such as the PID control algorithm through a pressure feedback mechanism, to control the supply of compressed air, so as to maintain stable pressure inside the reaction chamber 100 and avoid deflagration. For the second control valve 630 located at the outlet 102, it is only necessary to ensure that it is in a normally open state and maintain oxygen-enriched introduction to make the exhaust gas to be fully combusted.

[0068] The step of controlling to reduce the opening of the first control valve 610 is specifically as follows: controlling to reduce the opening of the first control valve 610 to a first preset opening. It is easy to understand that the setting of the first preset opening can ensure that the first control valve 610 can always supply compressed air into the first combustion zone 210 while reducing the possibility of explosion in the first combustion zone 210.

[0069] Correspondingly, the step of controlling to reduce the opening of the second control valve 630 is specifically as follows: controlling to reduce the opening of the third control valve 650 to a second preset opening. Similar to the foregoing, the setting of the second preset opening can ensure that the third control valve 650 can always supply compressed air into the third combustion zone 250 while reducing the possibility of explosion in the third combustion zone 250.

[0070] On the basis of the above, the value of the first preset opening is less than that of the second preset opening. Based on the above configuration, in the first combustion zone 210, the flow rate of compressed air introduced under the control of the first control valve 610 is relatively low, and the reaction amount of exhaust gas is relatively small. Therefore, even if the pressure fluctuation in the first combustion zone 210 is the most significant, adjusting the opening of the first control valve 610 according to pressure feedback can make the first pressure value relatively stable and prevent the deflagration risk. In the third combustion zone 250, the flow rate of compressed air introduced under the control of the third control valve 650 is

relatively large, and the reaction amount of exhaust gas is relatively large. Similarly, even if the pressure fluctuation in the third combustion zone 250 is relatively significant, adjusting the opening of the third control valve 650 according to pressure feedback can make the second pressure value also relatively stable and prevent the deflagration risk.

[0071] To ensure the use safety of the reaction chamber 100, the time for the first control valve 610 to be adjusted from full opening to the first preset opening is defined as a first preset time, and the time for the third control valve 650 to be adjusted from full opening to the second preset opening is defined as a second preset time. On this basis, the first preset time is shorter than the second preset time.

[0072] It is easy to understand that according to the comparison between the first preset time and the second preset time, the first control valve 610 has a more sensitive response, can respond more quickly to adjust the opening and supplement the compressed air more accurately, so as to better adapt to the first combustion zone 210 with high temperature and high-concentration exhaust gas. For example, the first preset time may be 100 ms, and the second preset time may be 150 ms.

[0073] Referring again to FIG. 9, after step S300, i.e., after the step of controlling, in response to the difference between the first pressure value and the first preset pressure value being greater than the first preset range, to reduce the opening of the first control valve 610, the method further includes:

[0074] step S600: controlling to reduce a frequency of the exhaust fan 500.

[0075] In step S600, it is easy to understand that reducing the frequency of the exhaust fan 500 can reduce an exhaust air volume. Based on this, the reaction chamber 100 has a negative pressure zone, and a negative pressure value of the negative pressure zone is always within a preset range, facilitating the introduction of exhaust gas and compressed air.

[0076] Exemplarily, in cases where the openings of the first control valve 610 and the third control valve 650 are increased, the gas flow rate inside the reaction chamber 100 increases and the pressure rises. At this time, the frequency of the exhaust fan 500 is also increased accordingly to ensure timely discharge of purified exhaust gas. In cases where the openings of the first control valve 610 and the third control valve 650 are decreased, the gas flow rate inside the reaction chamber 100 decreases and the pressure drops, and the frequency of the exhaust fan 500 is also decreased accordingly to maintain the negative pressure zone inside the reaction chamber 100 and ensure timely supplement of compressed air.

[0077] Optionally, the specific step of controlling to reduce the frequency of the exhaust fan 500 is as follows: controlling to reduce the frequency of the exhaust fan 500 to a preset frequency. Herein, the preset frequency corresponds to the first preset opening in the foregoing.

[0078] Based on the above, before step S600, an opening adjustment instruction for the first control valve 610 can be acquired as negative feedback for air volume adjustment. Based on the above feedback adjustment mechanism, the exhaust fan 500 can also use the PID control algorithm to adjust the frequency. Optionally, in the exhaust fan 500 system, the PID controller takes a pressure difference between the first pressure value and the first preset pressure value as an input, and effectively controls a load of the exhaust fan 500 by adjusting an output frequency of a frequency converter, thereby effectively controlling an air volume of the exhaust fan 500 and ensuring that the negative pressure value inside the reaction chamber 100 is within a preset range.

[0079] It should be noted that the exhaust fan 500 and the first control valve 610 are both self-regulated through the PID control algorithm, and the two can be cooperatively regulated and controlled, so as to ensure orderly progress of staged combustion, maintain stable pressure inside the reaction chamber 100, and achieve the beneficial effect of preventing the deflagration risk.

[0080] In addition, it should be noted that during the process from step S100 to step S600, i.e., during the flow through the high-temperature reaction chamber 100, the exhaust gas undergoes combustion reaction with the compressed air input through the first air supplement port 103, the second air supplement port 104, and the third air supplement port 105 in sequence to realize purification. After step S600, the purified exhaust gas can enter a water tank or a washing tower for cooling before being discharged, which is not limited herein.

[0081] Referring to FIG. 10, to execute possible steps of the exhaust gas combustion control method provided in the above embodiments, embodiments of the present disclosure provide an exhaust gas combustion control apparatus 30 applied to the combustion system 10 in the foregoing embodiments and configured to execute the above exhaust gas combustion control method. It should be noted that the basic principle of and technical effects produced by the exhaust gas combustion control apparatus 30 provided in the embodiments of the present disclosure are substantially the same as those of the above embodiments. For the sake of brief description, reference may be made to corresponding contents in the above embodiments for parts not mentioned in the present embodiment.

[0082] Optionally, the exhaust gas combustion control apparatus 30 provided in the present embodiment may include an acquisition module 31, a first control module 33, and a second control module 35.

[0083] Herein, the acquisition module 31 is configured to acquire a first pressure value inside the reaction chamber 100. Optionally, the acquisition module 31 may be specifically configured to execute step S100 in the above control method to achieve corresponding technical effects.

[0084] The first control module 33 is configured to control the exhaust fan 500, the first control valve 610, and the second control valve 630 to open. Optionally, the first control module 33 may be specifically configured to execute step S200 in the above control method to achieve corresponding technical effects.

[0085] The second control module 35 is configured to control, in response to the difference between the first pressure value and the first preset pressure value being greater than the first preset range, to reduce the opening of the first control valve 610. Optionally, the second control module 35 may be specifically configured to execute step S300 in the above control method to achieve corresponding technical effects.

[0086] The acquisition module 31 is further configured to acquire a second pressure value inside the reaction chamber 100. That is, the acquisition module 31 is further configured to execute step S400 in the above control method to achieve corresponding technical effects. Correspondingly, the first control module 33 is further configured to control the third control valve 650 to open. In practical application scenarios, the first control module 33 is configured to control the exhaust fan 500, the first control valve 610, and the second control valve 630 to open and simultaneously to control the third control valve 650 to open. Correspondingly, the second control module 35 is further configured to control, in response to the difference between the second pressure value and the second preset pressure value being greater than the second preset range, to reduce the opening of the third control valve 650. That is, the second control module 35 is further configured to execute step S500 in the above control method to achieve corresponding technical effects.

[0087] In addition, referring to FIG. 11, which is a structural schematic block diagram of an electronic device 20 provided in the present embodiment, the present disclosure further provides the electronic device 20, where the electronic device 20 may further include a memory 21 and one or more processors 23.

[0088] The memory 21 and the processor 23 are directly or indirectly electrically connected to each other to realize data transmission or interaction. For example, these elements may be electrically connected to each other through one or more communication buses or signal lines. The exhaust gas combustion control apparatus 30 includes at least one software function module that can be stored in the memory 21 in the form of software or firmware or solidified in an operating system (OS) of a server. The processor 23 is configured to execute executable modules

stored in the memory 21, such as software function modules and computer programs included in the exhaust gas combustion control apparatus 30.

[0089] Herein, the memory 21 may be, but is not limited to, random access memory 21 (RAM), read-only memory 21 (ROM), programmable read-only memory 21 (PROM), erasable programmable read-only memory 21 (EPROM), electrically erasable programmable read-only memory 21 (EEPROM), etc. Herein, the memory 21 is configured to store computer program codes including computer instructions, and when one or more processors 23 execute the computer instructions, the one or more processors 23 are caused to execute the exhaust gas combustion control method.

[0090] In addition, some embodiments of the present disclosure further provide a computer-readable storage medium, where the computer-readable storage medium stores a computer program, and the computer program, when executed by the processor 23, implements the exhaust gas combustion control method provided in any of the above embodiments.

[0091] In several embodiments provided by the present disclosure, it should be understood that the disclosed apparatus and method may also be implemented in other manners. The apparatus embodiments described above are only illustrative. For example, the flowcharts and block diagrams in the drawings show the possible architecture, functions, and operations of the apparatus, method, and computer program product according to multiple embodiments of the present disclosure. In this regard, each block in the flowcharts or block diagrams may represent a module, a program segment, or a part of code, and the module, program segment, or part of code includes one or more executable instructions configured to implement specified logical functions. It should also be noted that the functions marked in the blocks may also occur in a different order from that marked in the drawings in some alternative implementation modes. For example, two consecutive blocks may actually be executed substantially in parallel, and they may sometimes be executed in a reverse order, depending on the functions involved. It should also be noted that each block in the block diagrams and/or flowcharts, and combinations of blocks in the block diagrams and/or flowcharts, may be implemented by a dedicated hardware-based system that executes specified functions or actions, or may be implemented by a combination of dedicated hardware and computer instructions.

[0092] In addition, each function module in each embodiment of the present disclosure may be integrated together to form an independent part, or each module may exist alone, or two or more modules may be integrated together to form an independent part.

[0093] If the functions are implemented in the form of software function modules and sold or used as independent products, they may be stored in a computer-readable storage medium. Based

on such understanding, the technical solutions of the present disclosure essentially, or a part contributing to the prior art, or a part of the technical solution may be embodied in the form of a software product stored in a storage medium, including several instructions to cause a computer device (which may be a personal computer, a server, or a network device, etc.) to execute all or part of the steps of the method in each embodiment of the present disclosure. The foregoing storage medium includes: a U disk, a mobile hard disk, a read-only memory 21 (ROM), a random access memory 21 (RAM), a magnetic disk, an optical disk, and other media that can store program codes.

[0094] The above are only for specific embodiments of the present disclosure, but the scope of protection of the present disclosure is not limited thereto. Changes or replacements that could be readily conceived by those skilled in the art within the technical scope disclosed by the present disclosure shall fall within the scope of protection of the present disclosure.

INDUSTRIAL APPLICABILITY

[0095] In summary, the present disclosure provides a combustion system, an exhaust gas combustion control method, an exhaust gas combustion control apparatus, an electronic device, and a computer-readable storage medium, which can ensure the thorough combustion and purification of the exhaust gas and prevent the deflagration risk.