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TITLE OF THE INVENTION

PULSE COMBUSTOR

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a pulse combustor, which separately supplies a rich mixture of primary air and gaseous fuel and a secondary air to a combustion chamber thereof for continuous combustion.

Description of the Related Art

A typical example of conventional pulse combustors for pulsative ignition and continuous combustion of an air/fuel mixture is disclosed in US Patent No. 4,891,003 (Japanese Patent Laying-Open Gazette No. Sho-64-23005). The prior art pulse combustor, as shown in Fig. 7, includes a cylindrical combustion chamber 1, a nozzle plate 4 with a plurality of gas nozzles 2 and a plurality of air nozzles 3 arranged in the combustion chamber 1, and a circular resistant plate 5 disposed opposite to the nozzle plate 4 via a predetermined narrow space S. A jet of rich air/fuel mixture running through a gas conduit 6 is supplied from each of the gas nozzles 2 to the combustion chamber 1 while a jet of secondary air fed to an air chamber 8 by means of a fan 7 is supplied from each of the air nozzles 3 to the combustion chamber 1. The rich air/fuel mixture and the secondary air are sufficiently mixed between the resistant plate 5 and the nozzle plate 4, and ignited by a spark of an ignition plug 9 in the combustion chamber 1 for pulse combustion. A large portion of hot combustion byproducts is exhausted through a tail pipe 10. Although the high explosion pressure in the

combustion chamber 1 tends to cause a back flow of the combustion byproducts to the supply source, the resistant plate 5 in the combustion chamber 1 prevents such undesirable back flow. Exhaustion of the combustion byproducts makes the pressure in the combustion chamber 1 negative, so that another jet of the rich air/fuel mixture and that of the secondary air are successively fed into the combustion chamber 1 and spontaneously ignited and combusted by the residual hot exhausted gas in the combustion chamber 1. Ignition and combustion are periodically repeated in the above manner to heat an object like cooking oil in an oil tank.

In the system of the prior art pulse combustor, however, combustion byproducts once flown back to the supply source are not effectively mixed with the rich air/fuel mixture and the secondary air nor returned to the combustion chamber 1. Relatively high supply pressures of the rich air/fuel mixture and the secondary air as well as the resistant plate 5 are required for efficiently preventing the back flow of combustion byproducts. More concretely, the pulse combustor of the prior art system requires a high-pressure fan or a compressor for supplying the high-pressure air and a complicated, rather bulky gas supply unit for supplying the high-pressure fuel gas. These structures unfavorably increase the noise and vibration.

Furthermore, in the prior art system, the rich air/fuel mixture and the secondary air are mixed only in the predetermined narrow space S between the resistant plate 5 and the nozzle plate 4, which causes non-uniform mixing and





thereby unstable combustion.

SUMMARY OF THE INVENTION

The object of the invention is to provide a simply constructed, improved pulse combustor which realizes stable, continuous combustion with reduced noise and vibration.

The above and other related objects are realized by a pulse combustor of the invention, wherein a rich mixture of primary air and gaseous fuel and a secondary air are separately supplied to a cylindrical combustion chamber for pulsative ignition and continuous combustion of an appropriate air/fuel mixture.

The pulse combustor of the invention includes the cylindrical combustion chamber having a predetermined first volume for receiving the rich mixture of primary air and gaseous fuel and the secondary air separately, a tail pipe connecting to the combustion chamber for exhausting hot combustion byproducts sent from the combustion chamber, and a nozzle plate having a plurality of gas nozzles for supplying the rich mixture of primary air and gaseous fuel to the combustion chamber and a plurality of air nozzles for supplying the secondary air to the combustion chamber.

In the structure of the invention, the combustion chamber is defined by a first surface which the tail pipe is connected to, a cylindrical side wall, and the nozzle plate having the plurality of gas nozzles and air nozzles.

The pulse combustor of the invention further includes, as improvement, a flame baffle unit disposed opposite to the nozzle plate via a predetermined space for absorbing heat and reverse pressure generated by the hot combustion byproducts back flown from the combustion chamber, an air supply unit



having a predetermined second volume which is greater than the predetermined first volume, for supplying the secondary air to the combustion chamber through the plurality of air nozzles and receiving the hot combustion byproducts back flown from the combustion chamber, an ever-on fan for continuously feeding the secondary air to the air supply unit, and a specific system for mixing the secondary air continuously fed to air supply unit by means of the fan with the hot combustion byproducts back flown from the combustion chamber and received by the air supply unit, and feeding mixture of the secondary air and the hot combustion byproducts back to the combustion chamber via the plurality of air nozzles.

In the pulse combustor of the invention thus constructed, the rich mixture of primary air and gaseous fuel (hereinafter referred to as the rich air/fuel mixture) is supplied from the plurality of gas nozzles whereas the secondary air is fed from the plurality of air nozzles. The rich air/fuel mixture and the secondary air are sufficiently mixed in the predetermined space between the nozzle plate and the flame baffle unit and then ignited in the combustion chamber for pulsative combustion. The large combustion pressure in the combustion chamber exhausts a large portion of hot combustion byproducts from the tail pipe while a small portion of the combustion byproducts is back flown to the air supply unit. Although the flame baffle unit effectively prevents the large reverse pressure from being applied directly into the air supply unit, the small portion of the hot combustion byproducts flows around the flame baffle unit to go back to



the air supply unit. In this pathway going around the flame baffle unit, the hot combustion byproducts are effectively cooled down, and this temperature drop further causes contraction in volume and lowers the pressure of the exhausted gas. The predetermined second volume of the air supply unit is greater than the predetermined first volume of the combustion chamber as described previously. Such a volume ratio significantly reduces the reverse pressure from the combustion chamber. The small portion of the combustion byproducts back flown to the air supply unit is sufficiently mixed with the secondary air and thereby does not cause any adverse effect on smooth combustion.

The secondary air continuously fed into the air supply unit by means of the ever-on fan is mixed with the back-flown combustion byproducts and fed to the combustion chamber via the plurality of air nozzles. In this structure, the reverse pressure from the combustion chamber is sufficiently reduced, and the fan used here for supplying the secondary air to the air supply unit does not require the high pressure or the large capacity, accordingly. The fan having the moderate capacity has favorably small noise and vibration. Furthermore, the back-flow of the combustion byproducts from the combustion chamber lowers the combustion pressure in the combustion chamber. These features of the invention allow the effective noise and vibration reduction.

The combustion efficiency is largely affected by the ratio of a second volume V_2 in the air supply unit (hereinafter referred to as the supply volume) to a first volume V_1 in the combustion chamber (hereinafter referred to as the combustion volume). As shown in Fig. 2, the concentration of carbon

monoxide expressed by the ratio of CO to CO₂ varies with the ratio of the supply volume V2 to the combustion volume V1. When the supply volume V2 is less than the combustion volume V1, the combustion efficiency is undesirably lowered. In the structure of the invention, the supply volume V2 is greater than the combustion volume V1, thus allowing sufficient reduction of the reverse pressure and realizing stable pulse combustion.

In one preferred application, the flame baffle unit includes a baffle plate disposed opposite to the nozzle plate via the predetermined space. The baffle plate extends to a predetermined length covering all of the plurality of air nozzles and gas nozzles on the nozzle plate.

In one alternative structure, the flame baffle unit includes a first baffle plate and a second baffle plate both extending to a predetermined length covering all of the plurality of air nozzles and gas nozzles on the nozzle plate. The first baffle plate has a first surface and a second surface, where the first surface is disposed opposite to the nozzle plate via the predetermined space and the second surface faces the second baffle plate via a predetermined distance.

In this structure, it is preferable that the flame baffle unit further includes a baffle ring disposed radially along the cylindrical side wall of the combustion chamber and between the first baffle plate and the second baffle plate. The first baffle plate, the baffle ring, and the second baffle plate are preferably spaced at substantially equal intervals.

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In another preferred application, the flame baffle unit includes a ring-shaped flame trap and a baffle plate disposed opposite to the nozzle plate via the predetermined space. The baffle plate extends to a predetermined length covering all of the air nozzles and gas nozzles on the nozzle plate whereas the ring-shaped flame trap is disposed radially between the baffle plate and the cylindrical side wall of the combustion chamber.

In still another structure of the invention, the flame baffle unit includes a baffle plate disposed opposite to the nozzle plate via the predetermined space. The baffle plate has a plurality of through holes and spans the side wall of the combustion chamber.

These and other objects, features, aspects, and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiment with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross sectional view schematically illustrating a pulse combustor as a first embodiment of the invention;

Fig. 2 is a graph showing the combustion efficiency plotted against the ratio of a supply volume V_2 to a combustion volume V_1 ;

Fig. 3 is a cross sectional view schematically illustrating a pulse combustor as a second embodiment of the invention;

Fig. 4 is an enlarged view showing an essential part of the pulse combustor of Fig. 3;

Fig. 5 shows an essential part of a pulse combustor



according to a third embodiment of the invention;

Fig. 6 is a cross sectional view illustrating a pulse combustor as a fourth embodiment of the invention; and

Fig. 7 is a cross sectional view schematically illustrating a conventional pulse combustor.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The structure and function of the present invention will become more apparent through description of preferred embodiments of the invention.

Fig. 1 is a cross sectional view schematically illustrating a pulse combustor according to a first embodiment of the invention. In the pulse combustor of the first embodiment, an air chamber 11 has a greater inner volume than the air chamber 8 of the conventional system shown in Fig. 7, and an ever-on fan 12 has a moderate capacity compared with the high-pressure fan 7 of the conventional system. The system of the first embodiment also includes a baffle plate 15 in place of the resistant plate 5. In this first embodiment and the subsequent embodiments, the same elements as those of the conventional system have the same numerals.

The structure of the first embodiment is described more in detail. The pulse combustor of the embodiment includes a cylindrical combustion chamber 1 having a predetermined first volume, the air chamber 11 having a predetermined second volume greater than the first volume, and a nozzle plate 4 disposed between the combustion chamber 1 and the air chamber 11 to function as a partition and separate the combustion chamber 1 from the air chamber 11. The nozzle plate 4 is



provided with a plurality of gas nozzles 2 for supplying a non-flammable rich mixture of primary air and gaseous fuel and a plurality of air nozzles 3 for supplying a secondary air. The air chamber 11 is in communication with the combustion chamber 1 through the plurality of air nozzles 3. The plurality of gas nozzles 2 are connected to a gas supply conduit 6.

The pulse combustor of the embodiment further includes the fan 12, for example, a multiblade fan, for feeding the secondary air, and an air supply conduit 14 coupled with and connected to the fan 12 to supply the secondary air to the air chamber 11. Since the air chamber 11 has a sufficiently large inner volume, the required capacity of the fan 12 is significantly reduced.

The combustion chamber 1 is further connected to a tail pipe 10 for exhausting hot combustion byproducts and a decoupler or expansion chamber 13 disposed in the middle of the tail pipe 10. The pulse combustor may include a plurality of tail pipes, which may be disposed on a side wall of the combustion chamber 1.

The baffle plate 15 is arranged in the combustion chamber 1 to be located opposite to the nozzle plate 4 via a predetermined narrow space S. The baffle plate 15 effectively absorbs the heat of the hot combustion byproducts back flown from the combustion chamber 1 to the air chamber 11.

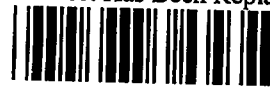
A jet of a rich mixture of primary air and gaseous fuel (hereinafter referred to as the rich air/fuel mixture) running through the gas supply conduit 6 is supplied to the combustion chamber 1 via each of the gas nozzles 2 on the



nozzle plate 4 as clearly seen in Fig. 1. A jet of secondary air fed to the air chamber 11 by means of the fan 12 is, on the other hand, supplied to the combustion chamber 1 via each of the air nozzles 3. The rich air/fuel mixture and the secondary air are sufficiently mixed in the predetermined space S between the baffle plate 15 and the nozzle plate 4 combusted in the combustion chamber 1. In this embodiment, the nozzle plate 4 has three gas nozzles 2 (diameter: 3 millimeter) and ten air nozzles 3 (diameter: 4 millimeter). The thickness of the baffle plate 15 is 4 millimeter, and the predetermined narrow space S between the baffle plate 15 and the nozzle plate 4 is equal to 3 millimeter.

The sufficiently mixed rich air/fuel mixture and secondary air (hereinafter referred to as the air/fuel mixture) is ignited with a spark of an ignition plug 9 in the combustion chamber 1 for pulse combustion.

The high explosion and combustion pressure in the combustion chamber 1 exhausts a large portion of hot combustion byproducts through the tail pipe 10 whereas a small portion of the hot combustion byproducts is back flown to the air chamber 11. Although the baffle plate 15 prevents the large reverse pressure from being applied into the air chamber 11 directly, the small portion of the combustion byproducts flows around the baffle plate 15 to go back to the air chamber 11. In this pathway going round the baffle plate 15, the hot combustion byproducts are effectively cooled down, and this temperature drop further causes contraction in volume and lowers the pressure of the exhausted gas. Since the second volume of the air chamber 11 is greater than the



first volume of the combustion chamber 1 as described previously, the reverse pressure from the combustion chamber 1 is significantly reduced, and the combustion byproducts back flown to the air chamber 1 is sufficiently mixed with the secondary air.

The secondary air continuously fed into the air chamber 11 by means of the ever-on fan 12 is mixed with the back-flown combustion byproducts and fed to the combustion chamber 1 via the plurality of air nozzles 3. Under such circumstances, the reverse pressure from the combustion chamber 1 is sufficiently low, and the fan 12 used here for supplying the secondary air to the air chamber 11 does not require the high pressure or the large capacity, accordingly. The fan 12 having the moderate capacity has favorably small noise and vibration. Furthermore, the back-flow of the combustion byproducts from the combustion chamber 1 lowers the combustion pressure in the combustion chamber 1, thus reducing the combustion noise. The turn-down ratio can be raised preferably by controlling the air supply volume fed by the fan 12 and the volume of the rich air/fuel mixture.

In the pulse combustor thus constructed, the combustion efficiency is largely affected by the ratio of a total volume V_2 of an air supply system (the volume of the air chamber 11 plus that of the air supply conduit 14: hereinafter referred to as the supply volume V_2) to a volume V_1 of the combustion chamber 1 (hereinafter referred to as the combustion volume V_1). Fig. 2 shows variation in the concentration of carbon monoxide (expressed as the ratio of CO/CO_2) plotted against the ratio of the supply volume V_2 to the combustion volume V_1 . In the range where the supply volume V_2 is less than the



combustion volume V_1 , the concentration of CO is significantly high; that is, the combustion efficiency is undesirably low. On the contrary, in the range where the supply volume V_2 is greater than the combustion volume V_1 , the CO concentration first abruptly decreases and then gradually increases with increase in the ratio of the supply volume V_2 to the combustion volume V_1 . In this range, the CO concentration is sufficiently low; that is, the combustion efficiency is preferably high.

The smaller supply volume V_2 than the combustion volume V_1 causes insufficient mixing of the back-flown combustion byproducts with the secondary air, thus lowering the combustion efficiency. Furthermore, the small supply volume V_2 does not sufficiently reduce the reverse pressure and requires a relatively large capacity of the fan 12.

When the supply volume V_2 is greater than the combustion volume V_1 , the smaller pressure loss and leaner air/fuel ratio increase the CO concentration only in the allowable range. In the embodiment, the supply volume V_2 is determined to be sufficiently larger than the combustion volume V_1 so as to lower the CO concentration to the minimum, thus significantly improving the combustion efficiency.

A second embodiment according to the invention is described with the accompanying drawings of Figs. 3 and 4. A pulse combustor of the second embodiment includes a plurality of baffle plates for improvement in heat absorption effects. More concretely, the pulse combustor as shown in Fig. 3 includes a first baffle plate 16 and a second baffle plate 17 both extending to a predetermined length covering all of the



plurality of air nozzles 3 and gas nozzles 2 on the nozzle plate 4. The first baffle plate 16 has a first surface and a second surface, where the first surface is disposed opposite to the nozzle plate 4 via a predetermined first distance and the second surface faces the second baffle plate 17 via a predetermined second distance. The first baffle plate 16 and the second baffle plate 17 have identical dimensions in this embodiment. The pulse combustor is further provided with a baffle ring 18 disposed radially along a cylindrical side wall of the combustion chamber 1 and between the first baffle plate 16 and the second baffle plate 17. In the preferred structure, the first baffle plate 16, the baffle ring 18, and the second baffle plate 17 are spaced at substantially equal intervals as clearly seen in Fig. 4. The heat of hot combustion byproducts back flown to the air chamber 11 is efficiently absorbed through a zigzag pathway through the second baffle plate 17, the baffle ring 18, and the first baffle plate 16.

Fig. 5 shows an essential part of another pulse combustor as a third embodiment of the invention. The pulse combustor of the third embodiment has a similar structure to that of the first embodiment, except a flame trap ring 19 arranged between a cylindrical side wall of the combustion chamber 1 and the baffle plate 15. The flame trap ring 19 has a ceramic honeycomb structure of 600 cells, where each cell denotes the number of pores in one square inch. The flame trap 19 and the baffle plate 15 of this structure also efficiently absorb the heat of hot combustion byproducts back flown to the air chamber 11 (see Fig. 1).

Fig. 6 shows still another pulse combustor as a fourth

embodiment according to the invention. In this structure, a punching metal 20 having a plurality of apertures 21 is disposed opposite to the nozzle plate 4 to span the whole length of the cylindrical combustion chamber 1. The plurality of apertures 21 formed in the punching metal 20 are arranged eccentrically with any of the plural gas nozzles 2 and the air nozzles 3. This eccentric structure effectively prevents the reverse pressure from the combustion chamber 1 from being applied into an air supply system directly. The structure of the fourth embodiment also ensures sufficient mixing of the back-flown combustion byproducts with the secondary air and efficiently absorbs the heat of the hot combustion byproducts.

As described above, in the pulse combustor of the invention, the supply volume is set greater than the combustion volume to allow the combustion byproducts to be partly back flown to the air supply system. The back-flown combustion byproducts are sufficiently mixed with the secondary air continuously fed by means of the ever-on fan and fed back to the combustion chamber. Such a system attains favorable combustion without the large capacity of the fan, and accordingly reduces undesirable noise and vibration to the minimum.

Since there may be many other modifications, changes, and alterations without departing from the scope or spirit of essential characteristics of the invention, it is clearly understood that the above embodiments are only illustrative and not restrictive in any sense. The spirit and scope of the present invention is limited only by the terms of the



appended claims.

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WHAT IS CLAIMED IS:

1. A pulse combustor for separately supplying a rich mixture of primary air and gaseous fuel and a secondary air to a combustion chamber for pulsative ignition and continuous combustion of an appropriate air/fuel mixture,

said pulse combustor comprising

said combustion chamber for receiving said rich mixture of primary air and gaseous fuel and said secondary air separately, said combustion chamber having a predetermined first volume,

discharge means connecting to said combustion chamber for exhausting hot combustion byproducts sent from said combustion chamber, and

a nozzle plate having a plurality of gas nozzles for supplying said rich mixture of primary air and gaseous fuel to said combustion chamber and a plurality of air nozzles for supplying said secondary air to said combustion chamber,

wherein said combustion chamber is defined by a first surface which said discharge means is connected to, a cylindrical side wall, and said nozzle plate having said plurality of gas nozzles and air nozzles,

said pulse combustor further comprising

flame baffle means disposed opposite to said nozzle plate via a predetermined space, said flame baffle means absorbing heat and reverse pressure generated by said hot combustion byproducts back flown from said combustion chamber,

air supply means for supplying said secondary air to said combustion chamber through said plurality of air nozzles, said air supply means having a predetermined second volume which is greater than said predetermined first volume, said



air supply means receiving said hot combustion byproducts back flown from said combustion chamber,

a fan for continuously feeding said secondary air to said air supply means, and

means for mixing said secondary air continuously supplied to said air supply means by means of said fan with said hot combustion byproducts back flown from said combustion chamber and received by said air supply means, and feeding mixture of said secondary air and said hot combustion byproducts back to said combustion chamber via said plurality of air nozzles.

2. A pulse combustor in accordance with claim 1, wherein said flame baffle means comprises a baffle plate disposed opposite to said nozzle plate via said predetermined space, said baffle plate extending to a predetermined length covering all of said plurality of air nozzles and gas nozzles on said nozzle plate.

3. A pulse combustor in accordance with claim 1, wherein said flame baffle means comprises a first baffle plate and a second baffle plate both extending to a predetermined length covering all of said plurality of air nozzles and gas nozzles on said nozzle plate, said first baffle plate having a first surface and a second surface where said first surface being disposed opposite to said nozzle plate via said predetermined space and said second surface facing said second baffle plate via a predetermined distance.

4. A pulse combustor in accordance with claim 3, wherein said flame baffle means further comprises a baffle ring disposed radially along said cylindrical side wall of said combustion chamber and between said first baffle plate and



said second baffle plate.

5. A pulse combustor in accordance with claim 4, wherein said first baffle plate, said baffle ring, and said second baffle plate are spaced at substantially equal intervals.

6. A pulse combustor in accordance with claim 1, wherein said flame baffle means comprises a ring-shaped flame trap and a baffle plate disposed opposite to said nozzle plate via said predetermined space, said baffle plate extending to a predetermined length covering all of said plurality of air nozzles and gas nozzles on said nozzle plate, said ring-shaped flame trap being disposed radially between said baffle plate and said cylindrical side wall of said combustion chamber.

7. A pulse combustor in accordance with claim 1, wherein said flame baffle means comprises a baffle plate disposed opposite to said nozzle plate via said predetermined space, said baffle plate having a plurality of through holes and spanning said side wall of said combustion chamber.

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