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(54) **COMBUSTOR AND GAS TURBINE**

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(57) **ABSTRACT**

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Provided is a combustor that includes a plurality of main burners disposed at intervals in a circumferential direction. The main burners include first main burners (16A) and second main burners (16B) that separately generate fuel-air mixtures. The second main burners (16B) generate fuel-air mixtures that have less evenness in concentration of fuel than the fuel-air mixtures generated by the first main burners (16A).

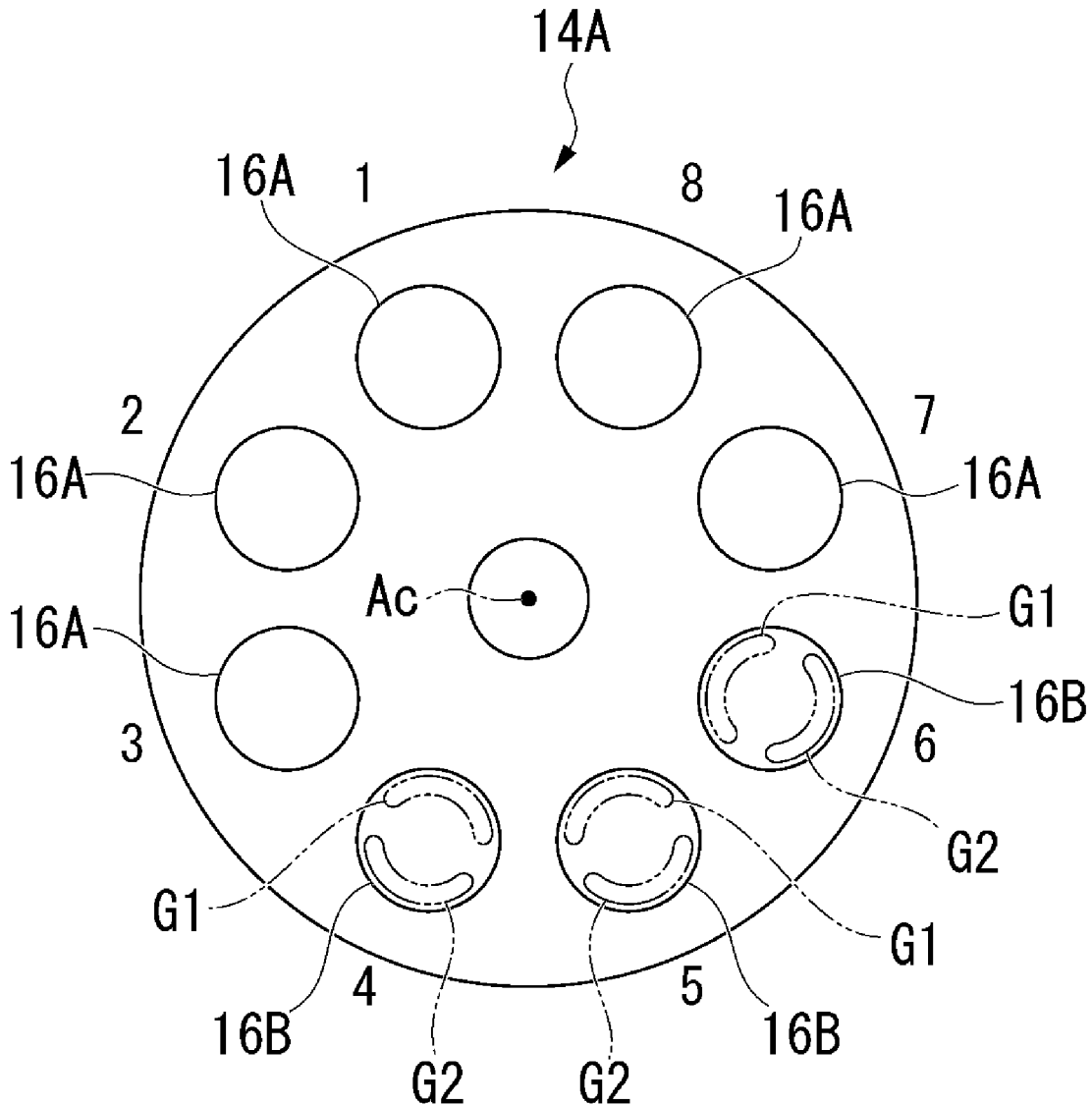


FIG. 1

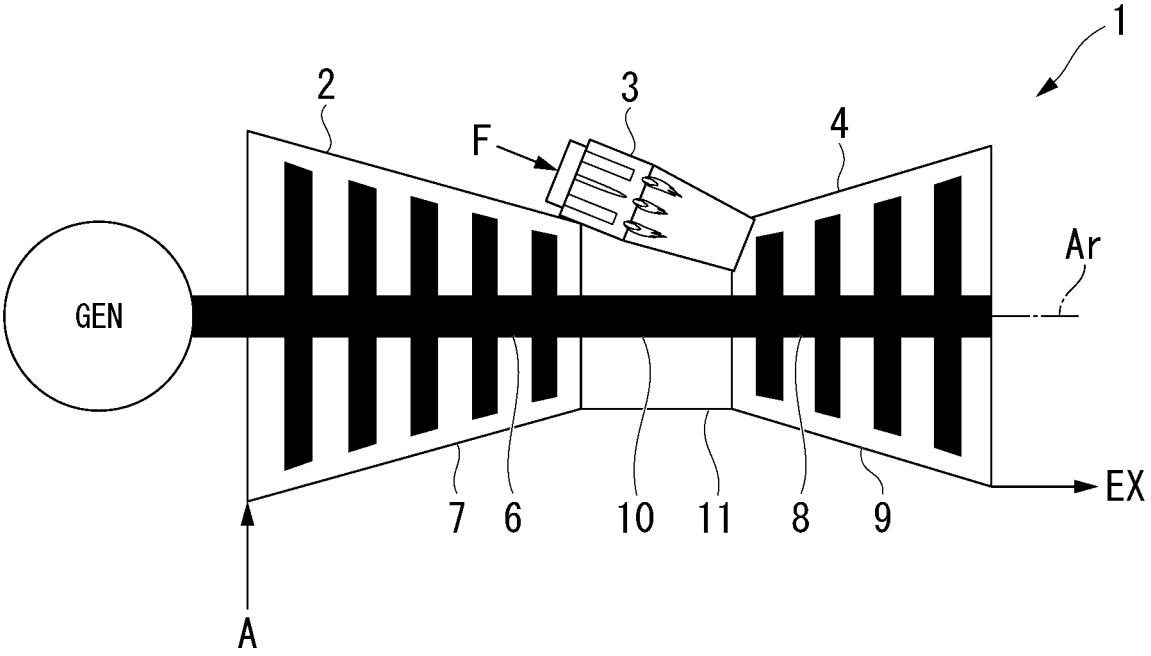


FIG. 2

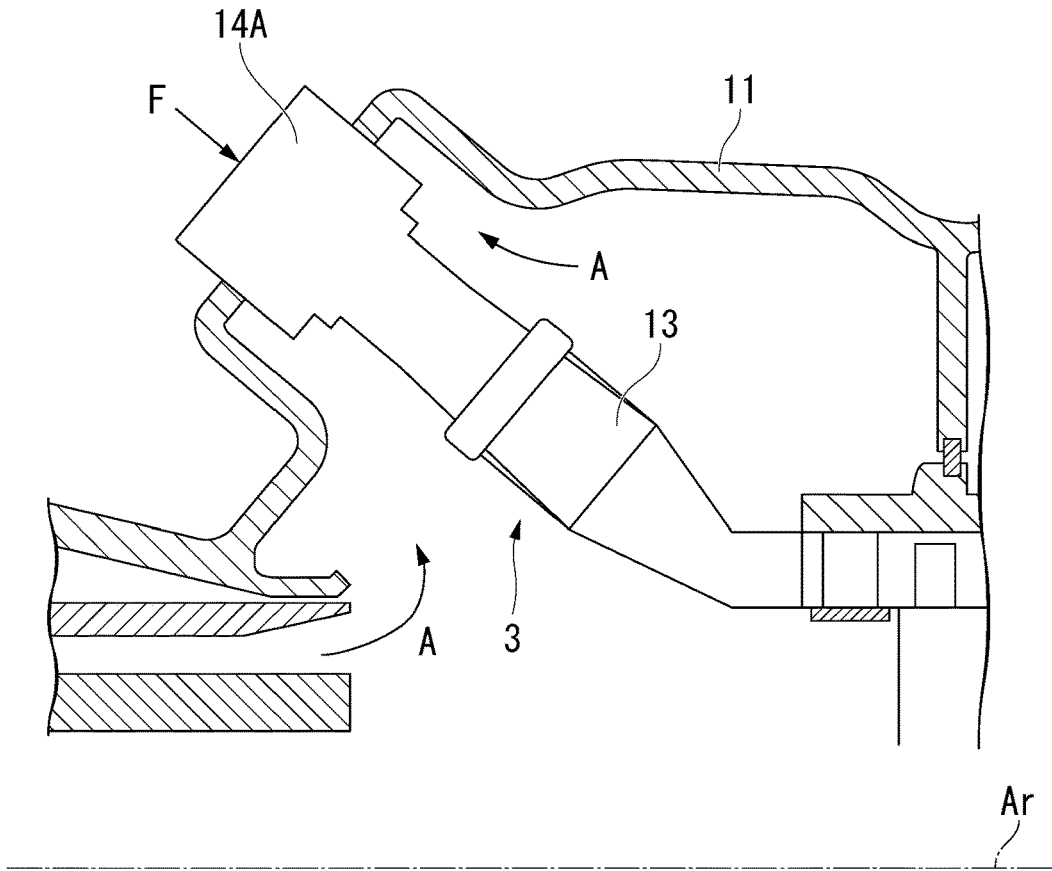


FIG. 3

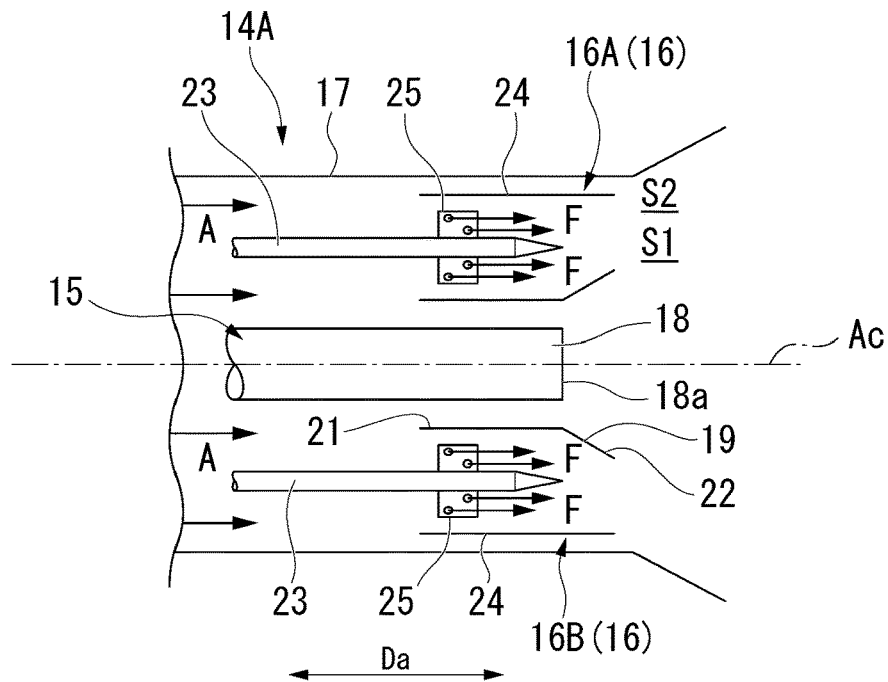


FIG. 4

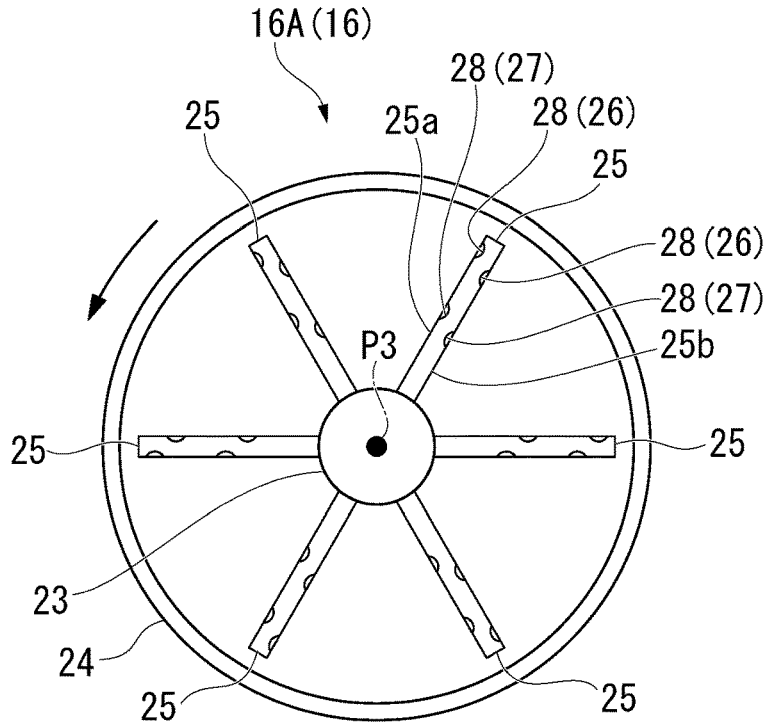


FIG. 5

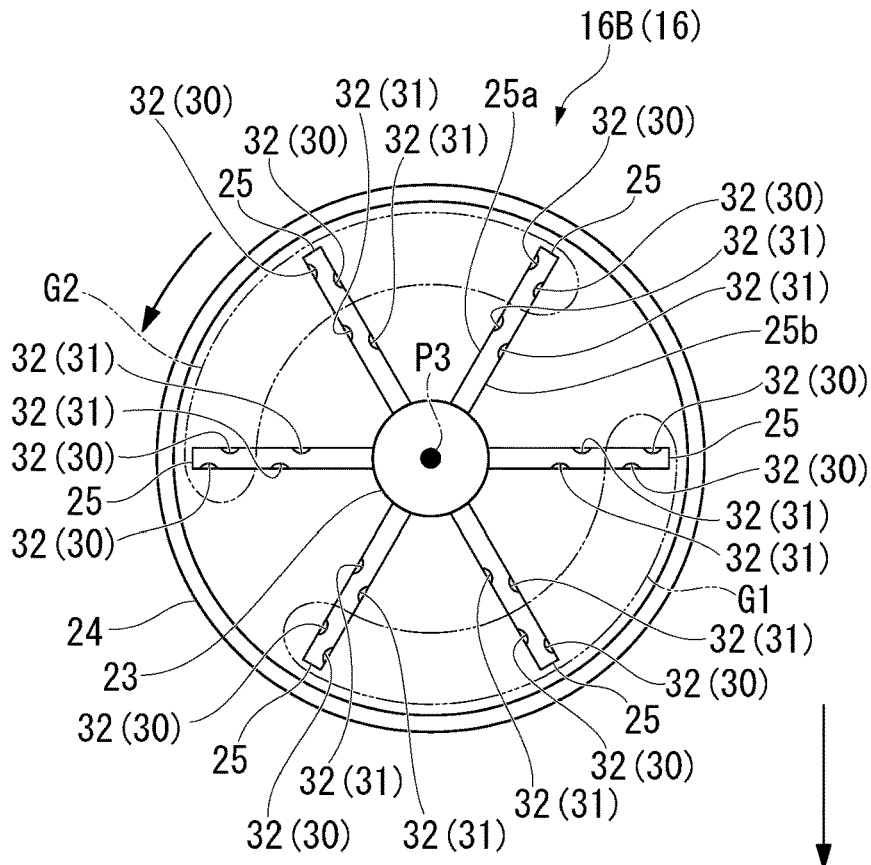


FIG. 6

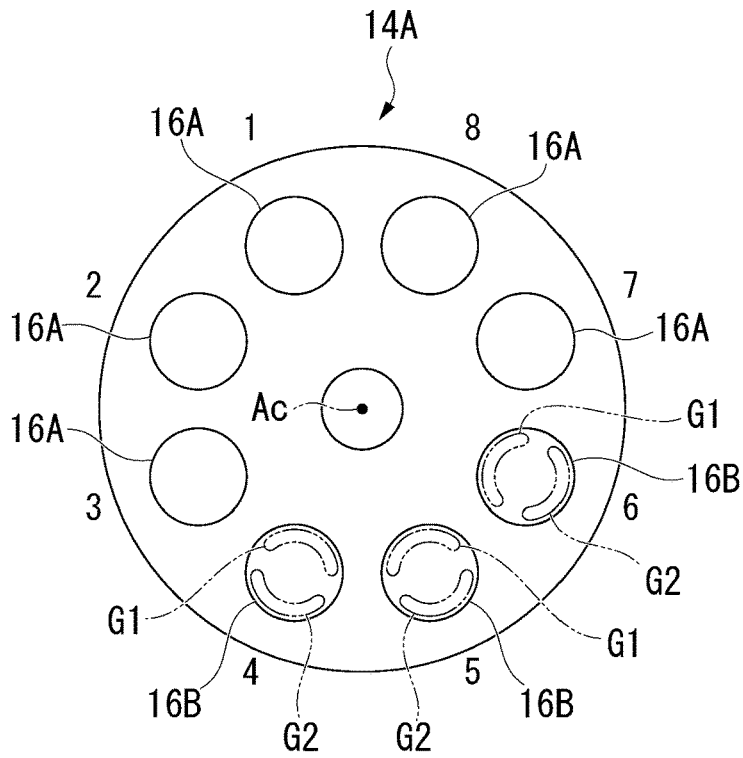


FIG. 7

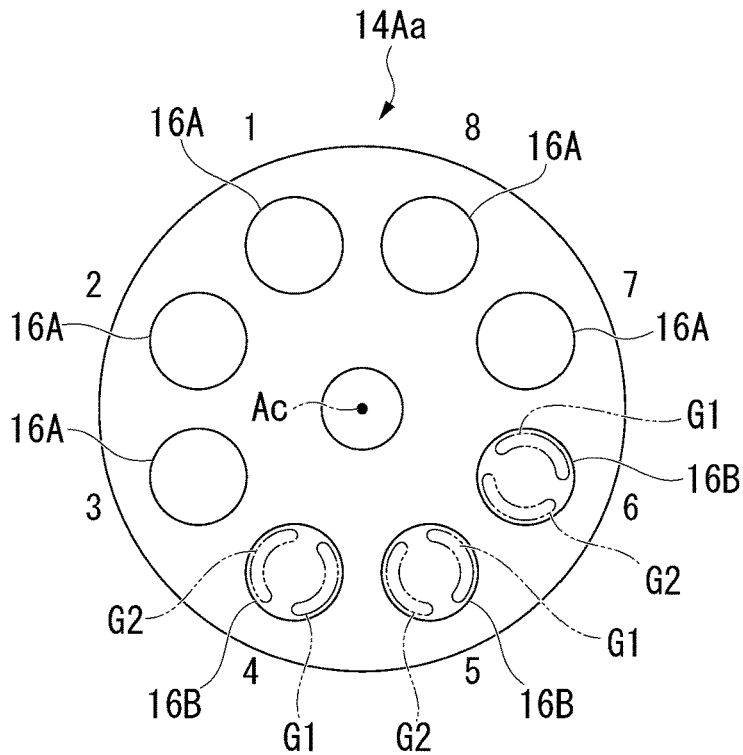


FIG. 8

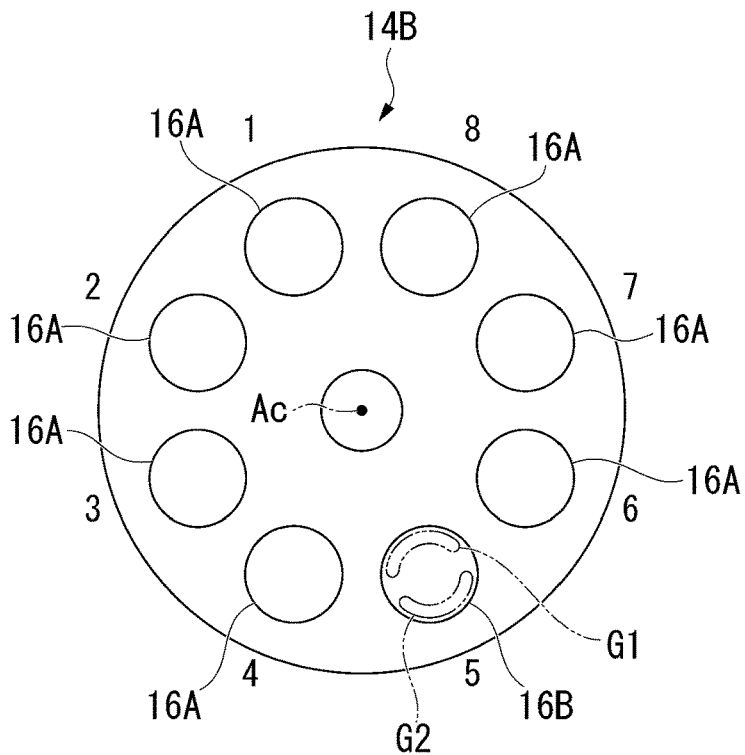


FIG. 9

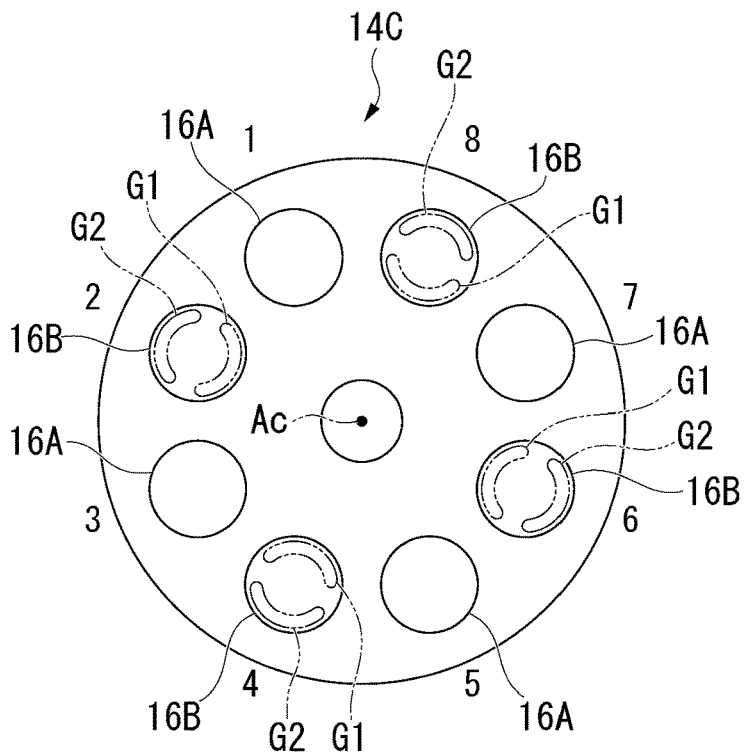
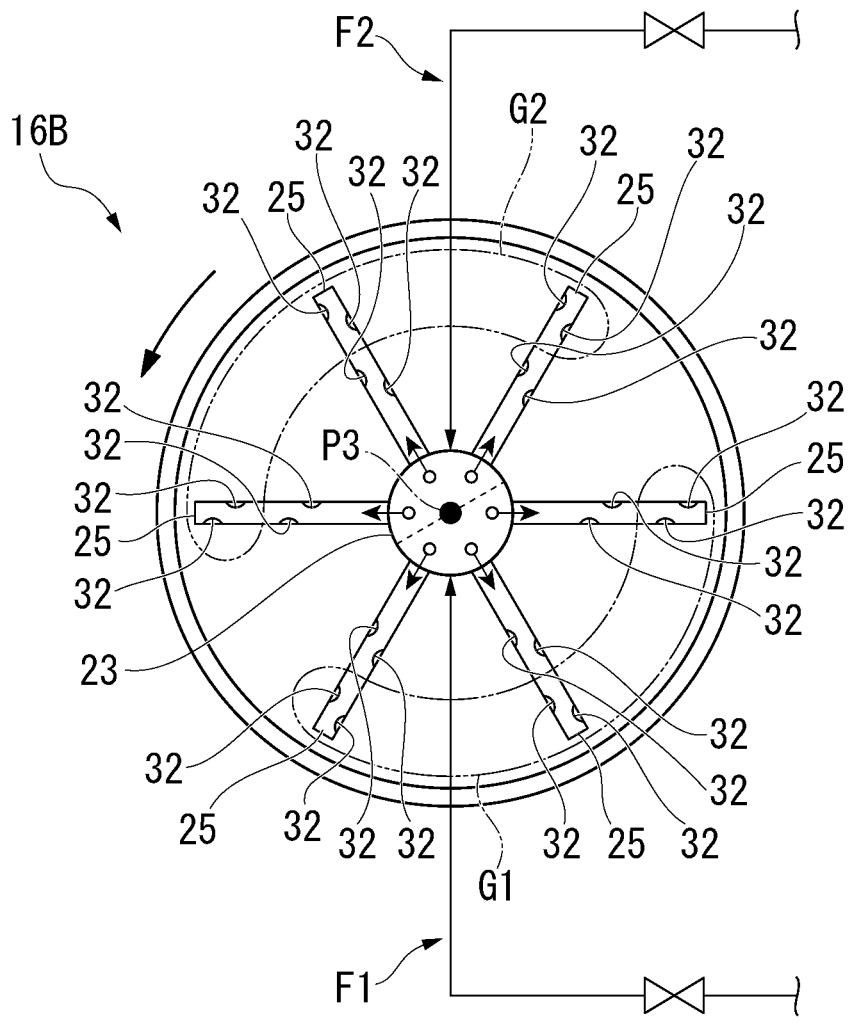


FIG. 10



COMBUSTOR AND GAS TURBINE

TECHNICAL FIELD

[0001] The present invention relates to a combustor and a gas turbine.

[0002] Priority is claimed on Japanese Patent Application No. 2017-140209, filed Jul. 19, 2017, the contents of which are incorporated herein by reference.

BACKGROUND ART

[0003] A combustor of a gas turbine having a plurality of main burners arranged around a pilot burner at regular intervals is known. In this combustor, there is a possibility of flames causing the same changes in a circumferential direction, that is, a possibility of combustion oscillations occurring, in a case where a change in pressure occurs in the main burners.

[0004] A technique for reducing an amount of fuel supplied from some of a plurality of main premixing nozzles to curb combustion oscillations is proposed in Patent Literature 1. According to the technique of Patent Literature 1, flames of a lean fuel-air premixture supplying a small amount of fuel can be formed into longer flames than flames of a fuel-air premixture in which a concentration of fuel is not reduced.

[0005] A technique for causing outlet shapes of elliptical extension tubes of some main nozzles to differ from outlet shapes of other main nozzles and shifting an ignition position to curb combustion oscillations is proposed in Patent Literature 2. According to the technique of Patent Literature 2, the combustion oscillations can be curbed by preventing generation of heat from being concentrated in a narrow region in an inner cylinder.

[0006] On the other hand, in a combustor of a gas turbine, it is desired to reduce nitrogen oxides (NO_x) or the like.

[0007] A technique for changing a concentration of fuel of a fuel-air premixture around a central axis of each nozzle such that a flame front is made even in an axial direction even if cooling air is intermixed in order to curb generation of nitrogen oxides is disclosed in Patent Literature 3.

CITATION LIST

Patent Literature

[Patent Literature 1]

[0008] Japanese Unexamined Patent Application, First Publication No. H11-294770

[Patent Literature 2]

[0009] Japanese Unexamined Patent Application, First Publication No. 2001-254947

[Patent Literature 3]

[0010] PCT International Publication No. WO2013/128572

SUMMARY OF INVENTION

Technical Problem

[0011] However, in the combustor disclosed in Patent Literature 1, since the amount of fuel supplied from some

main premixing nozzles is reduced, there is a possibility of a variation in fuel concentration distribution of the entire combustor becoming excessively large and of nitrogen oxides (NO_x) increasing.

[0012] The main burner disclosed in Patent Literature 2 can prevent fuel-air premixtures from all the main nozzles from being ignited and burnt at the same position, but there is still a possibility of a variation in fuel concentration distribution of the entire combustor becoming excessively large and of nitrogen oxides (NO_x) increasing.

[0013] On the other hand, in Patent Literatures 1 and 2, if an attempt is made to curb the nitrogen oxides (NO_x) to reduce the variation in fuel concentration distribution, there is a possibility of an increase in combustion oscillations.

[0014] Further, if an attempt is made to reduce the nitrogen oxides (NO_x) as in Patent Literature 3, there is a possibility of an increase in combustion oscillations.

[0015] The invention was made in view of the above circumstances, and an object of this invention is to provide a combustor and a gas turbine capable of inhibiting an increase in nitrogen oxides and generation of combustion oscillations.

Solution to Problem

[0016] The following constitutions are adopted to solve the above problems.

[0017] According to a first aspect of this invention, a combustor includes a plurality of main burners disposed at intervals in a circumferential direction. The main burners include first main burners and second main burners that separately generate fuel-air mixtures. The second main burners generate fuel-air mixtures that have less evenness in concentration of fuel than the fuel-air mixtures generated by the first main burners. The first main burners and the second main burners are disposed in an aperiodic disposition pattern over the entire circumference in the circumferential direction.

[0018] With this constitution, flames caused by the first main burners can be made slightly different from flames caused by the second main burners. For this reason, fuel concentration distribution can be inhibited from becoming uniform in the circumferential direction in which the main burners are disposed. On the other hand, the fuel concentration distribution can be inhibited from excessively varying in the entire combustor. The first main burners and the second main burners are not disposed in rotational symmetry, and thus can inhibit the flames from becoming uniform flames in the circumferential direction.

[0019] Therefore, an increase in nitrogen oxides and generation of combustion oscillations can be separately curbed.

[0020] According to a second aspect of this invention, the second main burners according to the first aspect may make the concentration of fuel of the fuel-air mixtures more uneven than that of the fuel-air mixtures of the first main burners in circumferential directions centered on main nozzles.

[0021] In this way, shapes of the flames caused by the second main burners can be slightly changed with respect to the flames caused by the first main burners in the circumferential directions of the main nozzles.

[0022] According to a third aspect of this invention, each of the second main burners according to the second aspect may include first fuel discharge holes that are disposed on a first side in the circumferential direction centered on the

main nozzle and discharge the fuel, and second fuel discharge holes that are disposed on a second side opposite to the first side in the circumferential direction centered on the main nozzle and discharge the fuel, and the second fuel discharge holes may have larger hole diameters than the first fuel discharge holes.

[0023] With this constitution, an amount of the fuel injected from the second fuel discharge holes can be increased more than that injected from the first fuel discharge holes. Therefore, the concentration of the fuel around the main nozzles can be easily made uneven in the second main burners.

[0024] According to a fourth aspect of this invention, each of the second main burners according to the second aspect may include: first fuel discharge holes that are disposed on a first side in the circumferential direction centered on the main nozzle and discharge the fuel; second fuel discharge holes that are disposed on a second side opposite to the first side in the circumferential direction centered on the main nozzle and discharge the fuel. The combustor may further include a first fuel supply system that supplies the fuel to the first fuel discharge holes; and a second fuel supply system that supplies the fuel to the second fuel discharge holes at a pressure different from that of the first fuel supply system.

[0025] With this constitution, the amount of the fuel injected from the first fuel discharge holes can be made different from that injected from the second fuel discharge holes without changing the hole diameters of the first fuel discharge holes and the second fuel discharge holes. Therefore, the concentration of the fuel around the main nozzles can be easily made uneven in the second main burners.

[0026] According to a fifth aspect of this invention, a gas turbine includes the combustor according to any one of the first to fourth aspects.

[0027] With this constitution, an unstable operation state resulting from combustion oscillations can be reduced, and generation of nitrogen oxides can be curbed. Therefore, saleability can be improved.

Advantageous Effects of Invention

[0028] According to the combustor and the gas turbine, an increase in nitrogen oxides and generation of combustion oscillations can be curbed.

BRIEF DESCRIPTION OF DRAWINGS

[0029] FIG. 1 is a view illustrating a schematic constitution of a gas turbine in a first embodiment of this invention.

[0030] FIG. 2 is a view illustrating a schematic constitution of a combustor in the first embodiment of this invention.

[0031] FIG. 3 is a view illustrating disposition of main burners in the first embodiment of this invention.

[0032] FIG. 4 is a front view illustrating a schematic constitution of a first main burner in the first embodiment of this invention.

[0033] FIG. 5 is a front view illustrating a schematic constitution of a second main burner in the first embodiment of this invention.

[0034] FIG. 6 is a front view illustrating disposition of the first main burners and the second main burners in the first embodiment of this invention.

[0035] FIG. 7 is a front view equivalent to FIG. 6 in a modification of the first embodiment of this invention.

[0036] FIG. 8 is a view equivalent to FIG. 6 in a second embodiment of this invention.

[0037] FIG. 9 is a view equivalent to FIG. 6 in a third embodiment of this invention.

[0038] FIG. 10 is a front view equivalent to FIG. 6 in a fourth embodiment of this invention.

DESCRIPTION OF EMBODIMENTS

First Embodiment

[0039] Hereinafter, a combustor and a gas turbine in a first embodiment of this invention will be described based on the drawings.

[0040] FIG. 1 is a view illustrating a schematic constitution of a gas turbine in a first embodiment of this invention.

[0041] As illustrated in FIG. 1, a gas turbine 1 includes a compressor 2, combustors 3, and a turbine 4.

[0042] The compressor 2 compresses air A to generate compressed air. The combustors 3 burn a fuel F in the compressed air generated by the compressor 2, and generate a high-temperature high-pressure combustion gas. The turbine 4 is driven by the combustion gas generated by the combustor 3 and converts energy of the combustion gas into rotation energy.

[0043] The compressor 2 includes a compressor rotor 6 and a compressor casing 7. Further, the turbine 4 includes a turbine rotor 8 and a turbine casing 9.

[0044] The compressor rotor 6 and the turbine rotor 8 are disposed in series and rotate about a rotation axis Ar. The turbine rotor 8 and the compressor rotor 6 are integrally connected, and a gas turbine rotor 10 is made up of the compressor rotor 6 and the turbine rotor 8. For example, a rotor of an electric generator GEN is connected to the gas turbine rotor 10.

[0045] The compressor casing 7 covers and rotatably supports the compressor rotor 6. Likewise, the turbine casing 9 covers and rotatably supports the turbine rotor 8. The compressor casing 7 and the turbine casing 9 are connected, and a gas turbine casing 11 is made up of the compressor casing 7 and the turbine casing 9. The combustor 3 is fixed to the gas turbine casing 11.

[0046] FIG. 2 is a view illustrating a schematic constitution of a combustor in the first embodiment of this invention. FIG. 3 is a view illustrating disposition of main burners in the first embodiment of this invention.

[0047] As illustrated in FIG. 2, the combustor 3 includes a combustion liner (or a transition piece) 13 and a fuel injector 14A. The combustion liner 13 burns the fuel F therein, and sends a combustion gas generated by the combustion of the fuel F to the turbine 4. The fuel injector 14A ejects the fuel F and the compressed air A into the combustion liner 13.

[0048] As illustrated in FIG. 3, the fuel injector 14A includes a pilot burner 15, main burners 16, and a burner holding cylinder 17.

[0049] The pilot burner 15 is disposed on a combustor axis Ac, and diffuses and burns the fuel. The pilot burner 15 includes a pilot nozzle 18, a pilot burner shell 19, and pilot swirlers (not illustrated).

[0050] The pilot nozzle 18 is formed to extend in an axial direction Da centered on the combustor axis Ac. The pilot nozzle 18 has, for example, an injection hole 18a for fuel injection at a downstream side end thereof.

[0051] The pilot burner shell 19 includes a main body 21 and a cone 22. The main body 21 covers an outer circumference of the pilot nozzle 18. The cone 22 is disposed on a downstream side of the main body 21, and is formed to gradually increase in diameter toward the downstream side.

[0052] The pilot swirlers (not illustrated) are disposed on an upstream side in the axial direction D_a relative to a position at which the injection hole of the pilot nozzle 18 is formed. The pilot swirlers (not illustrated) swirl compressed air (primary air) A flowing from the upstream side with the combustor axis A_c as a swirling center. For example, the pilot swirlers (not illustrated) extend inward from an inner circumferential surface of the main body 21 of the pilot burner shell 19 in a radial direction. For example, the plurality of pilot swirlers (not illustrated) are formed at intervals in a circumferential direction.

[0053] In the pilot burner 15 having the aforementioned constitution, the compressed air A compressed by the compressor 2 flows into the pilot burner shell 19 from the upstream side. Further, a fuel is injected from the injection hole of the pilot nozzle 18. The fuel is ejected from the pilot burner shell 19 toward the combustion liner 13 along with the compressed air A to which a swirling component is given by the pilot swirlers (not illustrated), and diffused and burned in the combustion liner 13.

[0054] The plurality of main burners 16 are provided, are disposed to surround an outer circumference of the pilot burner 15, and pre-mix and burn the fuel. These main burners 16 are disposed at intervals, more particularly, at regular intervals in a circumferential direction centered on the combustor axis A_c . The main burners 16 in this embodiment include first main burners 16A and second main burners 16B. In the following description, in a case where there is no need to distinguish the first main burners 16A and the second main burners 16B, they may be referred to simply as the main burners 16. Further, in the first and second main burners 16A and 16B, common portions are given the same reference signs, and a duplicate description thereof is omitted.

[0055] Each of the first main burner 16A and the second main burner 16B includes a main nozzle 23, a main burner shell 24, and main swirlers 25.

[0056] The main nozzles 23 extend parallel to the combustor axis A_c . Each of the main nozzles 23 includes a fuel channel (not illustrated) in which a fuel flows.

[0057] The main burner shell 24 covers an outer circumference of the main nozzle 23. In the main burner shell 24 exemplified in FIG. 3, a portion thereof disposed inside in a radial direction centered on the combustor axis A_c serves as a part of the pilot burner shell 19.

[0058] The main swirlers 25 swirl the compressed air (the primary air) A flowing from the upstream side with the main nozzle 23 as a swirling center. The main swirlers 25 extend from an outer circumferential surface of the main burner shell 24. The plurality of main swirlers 25 are provided at intervals in a circumferential direction centered on the main nozzle 23 that is provided on each of the plurality of main burners 16.

[0059] The burner holding cylinder 17 holds the pilot burner 15 and the main burners 16 described above. To be more specific, the burner holding cylinder 17 holds the pilot

burner 15 and the main burners 16 such that the plurality of main burners 16 surround the outer circumference of the pilot burner 15.

[0060] FIG. 4 is a front view illustrating a schematic constitution of a first main burner in the first embodiment of this invention. FIG. 5 is a front view illustrating a schematic constitution of a second main burner in the first embodiment of this invention.

[0061] As illustrated in FIG. 4, each of the main swirlers 25 of a first main burner 16A includes fuel discharge parts 26 and 27.

[0062] Each of the fuel discharge parts 26 and 27 is made up of a pair of fuel discharge holes 28 formed in pressure and suction sides 25a and 25b of each of the main swirlers 25. The fuel discharge part 26 is formed at a position adjacent to an outward end of the main swirler 25 in a radial direction, and the fuel discharge part 27 is formed inside the fuel discharge part 26 in a radial direction.

[0063] The fuel discharge holes 28 communicate with the fuel channel of each of the main nozzles 23. These fuel discharge holes 28 are configured such that, in the fuel discharge parts 26 and 27, the fuel discharge hole 28 formed in the pressure side 25a is offset outside the fuel discharge hole 28, which is formed in the suction side 25b, in a radial direction.

[0064] The fuel discharge holes 28 formed in the first main burner 16A are formed around a nozzle central axis P_3 of the main nozzle 23 such that the concentration of the fuel F mixed with the compressed air A is made substantially even. In this embodiment, all the fuel discharge holes 28 of the fuel discharge parts 26 provided on the first main burner 16A have the same hole diameter. Similarly, all the fuel discharge holes 28 of the fuel discharge parts 27 provided on the first main burner 16A have the same hole diameter. As long as the fuel discharge holes 28 have hole diameters by which the concentration of the fuel is made substantially even in the circumferential direction, the embodiment is not limited to the case where the hole diameters of the fuel discharge holes 28 are made the same as described above.

[0065] As illustrated in FIG. 5, each of the main swirlers 25 of a second main burner 16B includes fuel discharge parts 30 and 31.

[0066] Each of the fuel discharge parts 30 and 31 is made up of a pair of fuel discharge holes 32 formed in the pressure and suction sides 25a and 25b of each of the main swirlers 25. The fuel discharge part 30 is formed at a position adjacent to an outward end of the main swirler 25 in a radial direction, and the fuel discharge part 31 is formed inside the fuel discharge part 30 in a radial direction.

[0067] The fuel discharge holes 32 communicate with the fuel channel of each of the main nozzles 23. These fuel discharge holes 32 are configured such that, in the fuel discharge parts 30 and 31, the fuel discharge hole 32 formed in the pressure side 25a is offset outside the fuel discharge hole 32, which is formed in the suction side 25b, in a radial direction.

[0068] The second main burners 16B change a concentration of fuel around a nozzle central axis P_3 compared to the first main burners 16A, and supply fuel-air premixtures to the combustion liner 13. In this embodiment, the second main burners 16B change the concentration of the fuel around the nozzle central axis P_3 , and supply the fuel-air premixtures to the combustion liner. In other words, the second main burners 16B generate the fuel-air premixtures

that have less evenness in the concentration of fuel than those generated by the first main burners 16A.

[0069] The plurality of fuel discharge holes 32 formed in the second main burner 16B are divided into a first group G1 and a second group G2. The fuel discharged from each of the fuel discharge holes 32 of the first group G1 reaches an inside first range S1 (see FIG. 3) in the radial direction centered on the combustor axis Ac. The fuel discharged from each of the fuel discharge holes 32 of the second group G2 reaches an outside second range S2 (see FIG. 3) in the radial direction centered on the combustor axis Ac.

[0070] In the first embodiment, the second main burner 16B has the first group G1 made up of the fuel discharge parts 30 of two main swirlers 25 located on an inner side (a second side in the circumferential direction) in the radial direction centered on the combustor axis Ac (see FIG. 3) and the fuel discharge part 30 of one main swirler 25 adjacent to these two main swirlers 25 in a swirling direction. Furthermore, the second main burner 16B has the second group G2 made up of the fuel discharge parts 30 of the remaining three main swirlers 25 including the two main swirlers 25 located on an outer side (a first side in the circumferential direction) in the radial direction centered on the combustor axis Ac (see FIG. 3). The fuel discharge holes 32 of the fuel discharge parts 30 belonging to the first group G1 differ in opening areas (hole diameters) from those of the fuel discharge parts 30 belonging to the second group G2. Each of the fuel discharge parts 31 of the six main swirlers 25 includes the fuel discharge holes 32 which are all the same size.

[0071] In the case of the opening areas (the hole diameters) of the fuel discharge holes 32 of the first embodiment, for example when the fuel discharge holes 32 in the fuel discharge parts 31 are set to "1," the fuel discharge holes 32 of the fuel discharge parts 30 belonging to the first group G1 are set to "0.9," and the fuel discharge holes 32 of the fuel discharge parts 30 belonging to the second group G2 are set to "1.1." With this constitution, when a pressure is applied to the fuel F in the fuel channel of each of the main nozzles 23, the fuel F having an amount corresponding to the opening area is discharged to the compressed air A from each of the fuel discharge holes 32.

[0072] That is, among the plurality of fuel discharge holes 32 formed in one of the main swirlers 25, a discharged amount of fuel of the fuel discharge holes 32 disposed on the outer side in the radial direction centered on the nozzle central axis P3 of the main nozzle 23 is different from that of the fuel discharge holes 32 disposed on the inner side in the radial direction. Furthermore, a discharged amount of fuel of each of the fuel discharge parts 30 of the six main swirlers 25 is divided into two types around the nozzle central axis P3 of the main nozzle 23.

[0073] FIG. 6 is a front view illustrating disposition of the first main burners and the second main burners in the first embodiment of this invention.

[0074] As illustrated in FIG. 6, the fuel injector 14A includes five first main burners 16A that are continuously arranged in the circumferential direction centered on the combustor axis Ac and three second main burners 16B that are continuously arranged in the circumferential direction as well.

[0075] Here, the case where the fuel injector 14A illustrated in FIG. 6 includes the eight main burners 16 is illustrated. However, the number of main burners 16 may be nine or more or seven or fewer as long as there are a plurality

of main burners 16. Further, the number of first main burners 16A and the number of second main burners 16B are not limited to the above numbers. The fuel injector 14A may include both the first main burners 16A and the second main burners 16B. In FIG. 6, positions of the eight main burners 16 arranged in the circumferential direction are indicated by disposition numbers "1" to "8."

[0076] The fuel injector 14A in the first embodiment has the first and second main burners 16A and 16B disposed in an aperiodic disposition pattern over the entire circumference in the circumferential direction. Here, "periodic disposition pattern" means that a pattern of the order in which the first and second main burners 16A and 16B are disposed is repeated only in the same pattern around the combustor axis Ac once in the circumferential direction. Examples of periodic patterns may include a case where the first and second main burners 16A and 16B are alternately disposed in the circumferential direction, a case where only the first main burners 16A are disposed, a case where only the second main burners 16B are disposed, and so on.

[0077] That is, the disposition pattern of the main burners 16 in the fuel injector 14A in the first embodiment is configured such that the pattern of the order in which the first and second main burners 16A and 16B are disposed is not repeated only in the same pattern around the combustor axis Ac once in the circumferential direction.

[0078] Further, the first and second main burners 16A and 16B of the fuel injector 14A in the first embodiment are disposed in an asymmetric disposition pattern in the circumferential direction centered on the combustor axis Ac. "Asymmetric disposition pattern in the circumferential direction" means that the first and second main burners 16A and 16B are not disposed in an order that has so-called rotational symmetry.

[0079] The second main burners 16B of the fuel injector 14A are disposed such that the first group G1 and the second group G2 are divided into the inner side and the outer side in the radial direction centered on the combustor axis Ac. That is, the concentration of the fuel of the fuel-air pre-mixtures is made uneven in the radial direction centered on the combustor axis Ac in places in which the second main burners 16B of the fuel injector 14A are disposed. In other words, the concentration of the fuel of the fuel-air pre-mixtures of the second main burners 16B is made uneven in the circumferential directions centered on the main nozzles 23. In the first embodiment, the case where the first group G1 is disposed on the inner side in the radial direction and the second group G2 is disposed on the outer side in the radial direction is given by way of example.

[0080] Therefore, according to the aforementioned first embodiment, flames caused by the first main burners 16A can be made slightly different from flames caused by the second main burners 16B. For this reason, the fuel concentration distribution can be inhibited from becoming uniform in the circumferential direction of the fuel injector 14A in which the main burners 16 are disposed. On the other hand, since a variation in the amount of the fuel discharged by the first main burners 16A and the second main burners 16B can be curbed, the fuel concentration distribution can be inhibited from excessively varying in the entire combustor 3. As a result, an increase in nitrogen oxides (NO_x) and generation of combustion oscillations can be separately curbed.

[0081] Furthermore, since the first main burners 16A and the second main burners 16B are not disposed in the

rotational symmetry, the fuel concentration distribution can be inhibited from becoming uniform in the circumferential direction.

[0082] Further, shapes of the flames caused by the second main burners 16B can be slightly changed with respect to the flames caused by the first main burners 16A in the circumferential direction centered on the nozzle central axis P3.

[0083] Furthermore, the hole diameters (the opening areas) of the fuel discharge holes 32 (the second fuel discharge holes) of the second group G2 are made larger than those of the fuel discharge holes 32 (the first fuel discharge holes) of the first group G1. For this reason, the amount of the fuel discharged from the fuel discharge holes 32 of the second group G2 can be made more than that discharged from the fuel discharge holes 32 of the first group G1. As a result, the concentration of the fuel around each of the main nozzles 23 (in other words, around each of the nozzle central axes P3) can be easily made uneven in the second main burners 16B.

[0084] Further, an unstable operation state resulting from combustion oscillations can be reduced, and generation of nitrogen oxides can be curbed. Thus, saleability of the combustor 3 can be improved.

Modification of the First Embodiment

[0085] FIG. 7 is a front view equivalent to FIG. 6 in a modification of the first embodiment of this invention.

[0086] In the fuel injector 14A of the aforementioned first embodiment, the case where the first group G1 and the second group G2 are separately divided and disposed in the radial direction centered on the combustor axis Ac has been described. However, the disposition of the first and second groups G1 and G2 in each of the second main burners 16B is not limited to the disposition exemplified in the first embodiment.

[0087] For example, like the fuel injector 14Aa illustrated in FIG. 7, the first and second groups G1 and G2 in each of the second main burners 16B may be separately divided and disposed in the circumferential direction centered on the combustor axis Ac.

[0088] Further, in the aforementioned first embodiment, the case where the first group G1 is disposed on the inner side in the radial direction centered on the combustor axis Ac and the second group G2 is disposed on the outer side in the radial direction centered on the combustor axis Ac has been given by way of example. However, as another modification, the first group G1 may be disposed on the outer side in the radial direction centered on the combustor axis Ac, and the second group G2 may be disposed on the inner side in the radial direction centered on the combustor axis Ac.

[0089] Furthermore, the case where the entire first groups G1 are disposed on any one of the inner and outer sides in the radial direction centered on the combustor axis Ac has been described. However, in one fuel injector 14A, both the second main burners 16B in which the first group G1 is disposed on the inner side in the radial direction centered on the combustor axis Ac and the second main burners 16B in which the first group G1 is disposed on the outer side in the radial direction centered on the combustor axis Ac may be separately provided.

[0090] Further, in the aforementioned first embodiment and modification, the case where only the second main burners 16B in which the first group G1 and the second group G2 are divided and disposed in the radial direction

centered on the combustor axis Ac are provided or the case where only the second main burners 16B in which the first group G1 and the second group G2 are divided and disposed in the circumferential direction centered on the combustor axis Ac are provided has been described. However, the second main burners 16B in which the disposition of the first group G1 and the second group G2 is divided in the radial direction centered on the combustor axis Ac and the second main burners 16B in which the disposition of the first group G1 and the second group G2 is divided in the circumferential direction centered on the combustor axis Ac may be mixed in the fuel injector 14A.

Second Embodiment

[0091] Next, a second embodiment of this invention will be described based on the drawings. The second embodiment changes the disposition pattern of the main burners with respect to the aforementioned first embodiment. For this reason, the same portions as the aforementioned first embodiment are described with the same reference signs, and duplicate description thereof is omitted.

[0092] FIG. 8 is a view equivalent to FIG. 6 in a second embodiment of this invention.

[0093] As illustrated in FIG. 8, like the fuel injector 14A of the aforementioned first embodiment, a fuel injector 14B in the second embodiment includes first main burners 16A and second main burners 16B that act as a plurality of main burners 16. As described in the first embodiment, the first main burners 16A and the second main burners 16B have the same constitution except that fuel concentration distributions are different.

[0094] In the second embodiment, the fuel injector 14B has seven first main burners 16A and only one second main burner 16B that are continuously disposed in a circumferential direction. As in FIG. 6, the case where the fuel injector 14B illustrated in FIG. 8 includes the eight main burners 16 is illustrated. However, the number of main burners 16 may be nine or more or seven or less as long as there are a plurality of main burners 16.

[0095] In the fuel injector 14B, only one second main burner 16B is provided and, thereby like the fuel injector 14A of the first embodiment, the first main burners 16A and the second main burner 16B are disposed in an aperiodic disposition pattern over the entire circumference in the circumferential direction.

[0096] Furthermore, the fuel injector 14B has the first main burners 16A and the second main burner 16B disposed in an aperiodic disposition pattern (a disposition pattern that is not in rotational symmetry) in the circumferential direction centered on a combustor axis Ac.

[0097] In FIG. 8, a case where a first group G1 is disposed on an outer side in a radial direction centered on the combustor axis Ac and a second group G2 is disposed on an inner side is given by way of example, but this invention is not limited to this disposition. For example, the disposition of the first group G1 and the second group G2 of FIG. 8 may be replaced. Further, the first group G1 and the second group G2 may be directed in any direction, for example in the radial direction and the circumferential direction centered on the combustor axis Ac.

[0098] Therefore, according to the aforementioned second embodiment, like the first embodiment, fuel concentration distribution caused by the first main burners 16A can be made slightly different from that caused by the second main

burner 16B. For this reason, flames can be inhibited from becoming uniform in the circumferential direction of the fuel injector 14A in which the main burners 16 are disposed. On the other hand, since an amount of fuel discharged by the first main burners 16A and the second main burner 16B is made even, the fuel concentration distribution can be inhibited from excessively varying in the entire combustor 3. As a result, an increase in nitrogen oxides (NO_x) and generation of combustion oscillations can be separately curbed.

Third Embodiment

[0099] Next, a third embodiment of this invention will be described on the basis of the drawings. Like the second embodiment, the third embodiment changes the disposition pattern of the main burners with respect to the aforementioned first embodiment. For this reason, the same portions as the aforementioned first embodiment are described with the same reference signs, and duplicate description thereof is omitted.

[0100] FIG. 9 is a view equivalent to FIG. 6 in a third embodiment of this invention.

[0101] As illustrated in FIG. 9, like the fuel injector 14A of the aforementioned first embodiment, a fuel injector 14C in the third embodiment includes first main burners 16A and second main burners 16B that act as a plurality of main burners 16. As described in the first embodiment, the first main burners 16A and the second main burners 16B have the same constitution except that the fuel concentration distributions are different.

[0102] In the third embodiment, the fuel injector 14C has four first main burners 16A as well as four second main burner 16B. Like the first embodiment, the case where the fuel injector 14C in the third embodiment includes the eight main burners 16 is illustrated. However, the number of main burners 16 may be nine or more or seven or less as long as there are a plurality of main burners 16.

[0103] In the fuel injector 14C in the third embodiment, the first main burners 16A and the second main burners 16B are alternately disposed in a circumferential direction centered on a combustor axis Ac.

[0104] Like the first and second embodiments, the second main burners 16B in the third embodiment also has a constitution in that disposition of first and second groups G1 and G2 is not limited to that illustrated in FIG. 9.

[0105] Therefore, according to the aforementioned third embodiment, like the first embodiment, fuel concentration distribution caused by the first main burners 16A can be made slightly different from that caused by the second main burners 16B. For this reason, the fuel concentration distribution can be inhibited from becoming uniform in a circumferential direction of the fuel injector 14A in which the main burners 16 are disposed. On the other hand, since an amount of fuel discharged by the first main burners 16A and the second main burners 16B is made even, the fuel concentration distribution can be inhibited from excessively varying in the entire combustor 3. As a result, an increase in nitrogen oxides (NO_x) and generation of combustion oscillations can be separately curbed.

Fourth Embodiment

[0106] Next, a fourth embodiment of this invention will be described on the basis of the drawings. The fourth embodiment is different from the aforementioned first embodiment

only in a constitution in which, in each main burner 16B, an injected amount of fuel of a first group G1 is made different from that of a second group G2. For this reason, the same portions as the aforementioned first embodiment are described with the same reference signs, and duplicate description thereof is omitted.

[0107] FIG. 10 is a front view equivalent to FIG. 6 in a fourth embodiment of this invention.

[0108] As illustrated in FIG. 10, a main nozzle 23 of the main burner 16B in the fourth embodiment includes a first fuel supply system F1 and a second fuel supply system F2 that are independent of each other. The main burner 16B includes fuel discharge holes 32 that communicate with the first fuel supply system F1 and belong to the first group G1, and fuel discharge holes 32 that communicate with the second fuel supply system F2 and belong to the second group G2.

[0109] The first fuel supply system F1 and the second fuel supply system F2 are different in supply pressure of fuel F from each other. The first fuel supply system F1 and the second fuel supply system F2 may separately adjust, for example, a discharged amount of the fuel F that is discharged from the fuel discharge holes 32 of main swirlers 25 belonging to the first group G1, and a discharged amount of the fuel F that is discharged from the fuel discharge holes 32 of main swirlers 25 belonging to the second group G2. In the fourth embodiment, like the ratio of the hole diameters of the fuel discharge holes 32 in the first group G1 and the second group G2 in the first embodiment, a pressure ratio between the fuel F supplied by the first fuel supply system F1 and the fuel F supplied by the second fuel supply system F2 may be set to 0.9:1.1.

[0110] Therefore, according to the aforementioned fourth embodiment, without changing the hole diameters of the fuel discharge holes 32 of the first group G1 and the hole diameters of the fuel discharge holes 32 of the second group G2, the amount of the fuel discharged from the fuel discharge holes 32 of the first group G1 can be made different from that discharged from the fuel discharge holes 32 of the second group G2. Therefore, a concentration of fuel around the main nozzle 23 can be easily made uneven in the second main burner 16B.

Other Embodiments

[0111] In the first to fourth embodiments, the disposition pattern of the first and second main burners 16A and 16B is made different, but may be a disposition pattern other than the aforementioned disposition patterns. The disposition pattern may include both the first main burners 16A and the second main burners 16B, and may be used as, for example, disposition patterns from Case 1 to Case 22 shown in the following table. In the following table, numbers "1" to "22" recorded in the leftmost column are cases, and numbers "1" to "8" recorded at the uppermost position in each column correspond to the positions "1" to "8" of the main burners 16 in the circumferential direction of each of the above embodiments. Further, the rightmost column is the "number" of second main burners 16B in one fuel injector. Furthermore, in Cases of the following table, a case where the first main burners 16A are disposed is set to "0," and a case where the second main burners 16B are disposed is set to "1". The disposition pattern of the main burners 16 is not limited to

those of the following table, and the disposition patterns of the following table may be disposition patterns rotated in the circumferential direction.

TABLE 1

Case	1	2	3	4	5	6	7	8	Number
1	0	0	0	0	0	0	0	1	1
2	0	0	0	0	0	0	1	1	2
3	0	0	0	0	0	1	0	1	
4	0	0	0	0	1	0	0	1	
5	0	0	0	1	0	0	0	1	
6	0	0	0	0	0	1	1	1	3
7	0	0	0	0	1	0	1	1	
8	0	0	0	0	1	1	0	1	
9	0	0	0	1	0	0	1	1	
10	0	0	0	1	0	1	0	1	
11	0	0	0	1	1	0	0	1	
12	0	0	1	0	0	1	0	1	
13	0	0	0	0	1	1	1	1	4
14	0	0	0	1	0	1	1	1	
15	0	0	0	1	1	0	1	1	
16	0	0	0	1	1	1	0	1	
17	0	0	1	0	0	1	1	1	
18	0	0	1	0	1	0	1	1	
19	0	0	1	0	1	1	0	1	
20	0	0	1	1	0	0	1	1	
21	0	0	1	1	0	1	0	1	
22	0	1	0	1	0	1	0	1	

EXAMPLES

[0112] Next, examples of the combustor having the fuel injector of each of the above embodiments will be described.

[0113] With regard to the disposition pattern in which the first main burners 16A and the second main burners 16B are disposed, magnitudes of combustion oscillations of Cases “1” to “22” shown in the above table were obtained by simulation.

Examples

[0114] Here, Case “1” involved disposition patterns obtained by rotating the disposition pattern of the second embodiment around the nozzle central axis P3, and substantially the same result was obtained from the disposition patterns. Further, Case “6” also involved disposition patterns obtained by rotating the disposition pattern of the first embodiment around the nozzle central axis P3, and substantially the same result was obtained from the disposition patterns. Case “22” involved disposition patterns identical to that of the third embodiment. Here, the three patterns of Cases “1,” “6” and “22” will be described as representative examples.

Comparative Examples

[0115] Although not shown in the above table, a case where all the main burners 16 of the fuel injectors 14A to 14C were the first main burners 16A is Comparative Example 1, and a case where all the main burners 16 were the second main burners 16B is Comparative Example 2.

[0116] (Combustion Oscillations)

[0117] With regard to Case “1,” Case “6,” Case “22,” and Comparative Examples 1 and 2, simulation calculation of pressure fluctuation caused by combustion oscillations was performed using a pressure and a frequency as parameters.

[0118] As a result of comparing the simulation results, it was confirmed that Cases “1,” “6” and “22” tended to have lower combustion oscillations than Comparative Examples 1 and 2.

[0119] Any of Cases “1,” “6” and “22” included both the first main burners 16A and the second main burners 16B. Especially, the combustion oscillations were remarkably reduced in Case “6”.

[0120] That is, it was confirmed that there was a correlation between the disposition pattern having both the first main burners 16A and the second main burners 16B and the reduction in combustion oscillations.

[0121] This invention is not limited to the constitutions of the above embodiments, and can include a change in design without departing from the gist of this invention.

[0122] In each embodiment, the case where the concentration of fuel in the first main burners 16A in the circumferential direction substantially becomes even has been described. However, the variation in the concentration of fuel in the first main burners 16A in the circumferential direction may be smaller than that in the second main burners 16B, and this invention is not limited to the case where the concentration of fuel is even.

[0123] Further, in each embodiment, the case where each of the second main burners 16B includes the first and second groups G1 and G2 having different injected amounts of fuel has been described. However, the number of groups having different injected amounts of fuel is not limited to two. Three or more groups may be formed. Further, depending on the number of groups which each of the second main burners 16B includes, a kind of the injected amount may be three or more.

[0124] Furthermore, the constitution in which each of the second main burners 16B generates the fuel-air premixture in which the concentration of fuel is uneven in the circumferential direction centered on the nozzle central axis P3 has been described. However, if the second main burners 16B can curb a variation in the flames of the entire combustor 3 while the flames caused by the fuel-air premixture generated by each of the second main burners 16B are made different from the flames caused by the fuel-air premixture generated by each of the first main burners 16A, the fuel-air premixture is not limited to the constitution in which the concentration of fuel is uneven in the circumferential direction centered on the nozzle central axis P3.

[0125] Further, in each embodiment, the case where the fuel discharge holes 28 and 32 are formed in the main swirlers 25 has been described. However, the fuel discharge holes 28 and 32 are not limited to being formed in the main swirlers 25. For example, the fuel discharge holes 28 and 32 may be formed in outer circumferential surfaces of the main nozzles 23.

[0126] Furthermore, the ratio between the hole diameters of the fuel discharge holes 32 of the first group G1 and the hole diameters of the fuel discharge holes 32 of the second group G2, and the ratio between the amount of the fuel discharged from the fuel discharge holes 32 of the first group G1 and the amount of the fuel discharged from the fuel discharge holes 32 of the second group G2 are not limited to the ratios of each of the above embodiments.

INDUSTRIAL APPLICABILITY

[0127] This invention can be applied to a combustor. According to this combustor, an increase in nitrogen oxides and generation of combustion oscillations can be separately curbed.

REFERENCE SIGNS LIST

- [0128] 1 Gas turbine
- [0129] 2 Compressor
- [0130] 3 Combustor
- [0131] 4 Turbine
- [0132] 6 Compressor rotor
- [0133] 7 Compressor casing
- [0134] 8 Turbine rotor
- [0135] 9 Turbine casing
- [0136] 10 Gas turbine rotor
- [0137] 11 Gas turbine casing
- [0138] 13 Combustion liner
- [0139] 14A, 14Aa, 14B, 14C, 14D Fuel injector
- [0140] 15 Pilot burner
- [0141] 16 Main burner
- [0142] 16A First main burner
- [0143] 16B Second main burner
- [0144] 17 Burner holding cylinder
- [0145] 18 Pilot nozzle
- [0146] 18a Injection hole
- [0147] 19 Pilot burner shell
- [0148] 21 Main body
- [0149] 22 Cone
- [0150] 23 Main nozzle
- [0151] 24 Main burner shell
- [0152] 25 Main swirler
- [0153] 25a Pressure side
- [0154] 25b Suction side
- [0155] 26, 27, 30, 31 Fuel discharge part
- [0156] 28, 32 Fuel discharge hole
- [0157] A Air, compressed air
- [0158] Ac Combustor axis
- [0159] Ar Rotation axis
- [0160] Da Axial direction
- [0161] F Fuel
- [0162] F1 First fuel supply system
- [0163] F2 Second fuel supply system
- [0164] G1 First group
- [0165] G2 Second group
- [0166] GEN Electric generator
- [0167] P3 Nozzle central axis
- [0168] S1 First range
- [0169] S2 Second range

1-5. (canceled)

6. A combustor comprising a plurality of main burners disposed at intervals in a circumferential direction, wherein the main burners include
 first main burners that generate fuel-air mixtures, and
 second main burners that generate fuel-air mixtures that have less evenness in concentration of fuel than the fuel-air mixtures generated by the first main burners, and
 the first main burners and the second main burners are disposed in an aperiodic disposition pattern over an entire circumference in the circumferential direction;
 the second main burners make the concentration of fuel of the fuel-air mixtures more uneven than that of the

fuel-air mixtures of the first main burners in circumferential directions centered on main nozzles;
 each of the second main burners includes
 first fuel discharge holes that are disposed on a first side in the circumferential direction centered on the main nozzle and discharge the fuel, and
 second fuel discharge holes that are disposed on a second side opposite to the first side in the circumferential direction centered on the main nozzle and discharge the fuel; and
 the first fuel discharge holes and the second fuel discharge holes are separately divided on an inner side and an outer side and disposed in the radial direction centered on the combustor axis.

7. A combustor comprising a plurality of main burners disposed at intervals in a circumferential direction, wherein the main burners include
 first main burners that generate fuel-air mixtures, and
 second main burners that generate fuel-air mixtures that have less evenness in concentration of fuel than the fuel-air mixtures generated by the first main burners;
 the first main burners and the second main burners are disposed in an aperiodic disposition pattern over an entire circumference in the circumferential direction;
 the second main burners make the concentration of fuel of the fuel-air mixtures more uneven than that of the fuel-air mixtures of the first main burners in circumferential directions centered on main nozzles;
 each of the second main burners includes
 first fuel discharge holes that are disposed on a first side in the circumferential direction centered on the main nozzle and discharge the fuel, and
 second fuel discharge holes that are disposed on a second side opposite to the first side in the circumferential direction centered on the main nozzle and discharge the fuel; and
 the first fuel discharge holes and the second fuel discharge holes are separately divided and disposed in the circumferential direction centered on the combustor axis.

8. A combustor comprising a plurality of main burners disposed at intervals in a circumferential direction, wherein the main burners include
 first main burners that generate fuel-air mixtures, and
 second main burners that generate fuel-air mixtures that have less evenness in concentration of fuel than the fuel-air mixtures generated by the first main burners;
 the first main burners and the second main burners are disposed in an aperiodic disposition pattern over an entire circumference in the circumferential direction;
 the second main burners make the concentration of fuel of the fuel-air mixtures more uneven than that of the fuel-air mixtures of the first main burners in circumferential directions centered on main nozzles;
 each of the second main burners includes
 first fuel discharge holes that are disposed on a first side in the circumferential direction centered on the main nozzle and discharge the fuel, and
 second fuel discharge holes that are disposed on a second side opposite to the first side in the circumferential direction centered on the main nozzle and discharge the fuel;
 the first fuel discharge holes and the second fuel discharge holes are separately divided on an inner side and an

- outer side and disposed in the radial direction centered on the combustor axis; and
the main burners as a plurality of the second main burners, includes both
- a second main burner in which the first fuel discharge holes are disposed radially inward in the radial direction centered on the combustor axis, and
 - a second main burner in which the first fuel discharge holes are disposed radially outward in the radial direction centered on the combustor axis.
- 9.** A combustor comprising a plurality of main burners disposed at intervals in a circumferential direction, wherein the main burners include
- first main burners that generate fuel-air mixtures, and
 - second main burners that generate fuel-air mixtures that have less evenness in concentration of fuel than the fuel-air mixtures generated by the first main burners;
- the first main burners and the second main burners are disposed in an aperiodic disposition pattern over an entire circumference in the circumferential direction; the second main burners make the concentration of fuel of the fuel-air mixtures more uneven than that of the fuel-air mixtures of the first main burners in circumferential directions centered on main nozzles;
- the main burners as a plurality of the second main burners, includes
- a second main burner having first fuel discharge holes that are disposed on a first side in the radial direction centered on the main nozzle and discharge the fuel, and second fuel discharge holes that are disposed on a second side opposite to the first side in the radial direction centered on the main nozzle and discharge the fuel, and
 - a second main burner having first fuel discharge holes that are disposed on a first side in the circumferential direction centered on the main nozzle and discharge the fuel, and second fuel discharge holes that are disposed on a second side opposite to the first side in the circumferential direction centered on the main nozzle and discharge the fuel.
- 10.** The combustor according to claim 6, wherein the second fuel discharge holes have larger hole diameters than the first fuel discharge holes.
- 11.** The combustor according to claim 7, wherein the second fuel discharge holes have larger hole diameters than the first fuel discharge holes.
- 12.** The combustor according to claim 8, wherein the second fuel discharge holes have larger hole diameters than the first fuel discharge holes.
- 13.** The combustor according to claim 9, wherein the second fuel discharge holes have larger hole diameters than the first fuel discharge holes.
- 14.** The combustor according to claim 6, further comprising:
- a first fuel supply system that supplies the fuel to the first fuel discharge holes; and
 - a second fuel supply system that supplies the fuel to the second fuel discharge holes at a pressure different from that of the first fuel supply system.
- 15.** The combustor according to claim 7, further comprising:
- a first fuel supply system that supplies the fuel to the first fuel discharge holes; and
 - a second fuel supply system that supplies the fuel to the second fuel discharge holes at a pressure different from that of the first fuel supply system.
- 16.** The combustor according to claim 8, further comprising:
- a first fuel supply system that supplies the fuel to the first fuel discharge holes; and
 - a second fuel supply system that supplies the fuel to the second fuel discharge holes at a pressure different from that of the first fuel supply system.
- 17.** The combustor according to claim 9, further comprising:
- a first fuel supply system that supplies the fuel to the first fuel discharge holes; and
 - a second fuel supply system that supplies the fuel to the second fuel discharge holes at a pressure different from that of the first fuel supply system.
- 18.** A gas turbine comprising the combustor according to claim 6.
- 19.** A gas turbine comprising the combustor according to claim 7.
- 20.** A gas turbine comprising the combustor according to claim 8.
- 21.** A gas turbine comprising the combustor according to claim 9.

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