CLAIMS

What is claimed is:

1. A method of injecting hydrogen into a combustion chamber of a combustor of a gas turbine system, the method comprising:

outputting a mixture of fuel and air into the combustion chamber via an outlet of an outer conduit in fluid communication with the combustion chamber to generate a first wake region; and

injecting at least one jet of hydrogen into the combustion chamber toward the first wake region via an outlet of an inner hydrogen injection conduit that is in fluid communication with the combustion chamber;

the outer conduit being positioned such that the outlet of the outer conduit is around an outer periphery of the outlet of the inner hydrogen injection conduit,

wherein the first wake region is downstream of the outlet of the inner hydrogen injection conduit and upstream of a position within the combustion chamber at which the mixture of fuel and air output from the outlet of the outer conduit crosses a discharge region of the outlet of the inner hydrogen injection conduit within the combustion chamber;

wherein a burner of the combustor includes the outer conduit and the injecting of the at least one jet of hydrogen into the combustion chamber via the outlet of the inner hydrogen injection conduit is performed to control operation of the gas turbine so that a ratio of hydrogen to fuel flow rate is provided so that an equivalence ratio for the combustor is equal to:

$$\frac{m, H2, central, max}{m, Fuel} \approx 0.5 * \left[\frac{m, recirc}{m, total}\right] * [\frac{1 - \Phi}{\Phi}]$$

where:

m,H2,central,max is a maximum allowable central hydrogen injection mass flow rate;

$\dot{m}_{Fuel}$ is a fuel flow rate of the fuel for the burner,

$\dot{m}_{recirc}$ is a mass flow recirculation rate in a first wake region of the burner;

$\dot{m}_{total}$ is a total burner flow rate; and

Φ is the equivalence ratio accounting for only the air and the fuel injected through the outlet of the outer conduit.

2. The method of claim 1, wherein a secondary wake region is formed by injecting the at least one jet of hydrogen toward the first wake region.

3. The method of claim 2, further comprising:

generating a swirl of air via at least one swirler to generate a swirling flow for the mixture of air and fuel prior to outputting the mixture of air and fuel from the outlet of the outer conduit; and

wherein the secondary wake region is between the outlet of the inner hydrogen injection conduit and the position within the combustion chamber at which the mixture of fuel and air output from the outlet of the outer conduit crosses the outlet of the inner hydrogen injection conduit while the fuel of the mixture combusts in the combustion chamber.

4. The method of claim 3, wherein the outlet of the inner hydrogen injection conduit is a single orifice and the inner hydrogen injection conduit has at least one cavity upstream of the single orifice.

5. The method of claim 4, wherein the at least one cavity has a depth, a cavity length, and a cavity trailing edge distance, which is a distance a downstream end of the cavity is from the outlet of the inner hydrogen injection conduit;

the cavity depth being greater than or equal to a radius of the orifice of the outlet of the inner hydrogen injection conduit and also be less than or equal to a diameter of the orifice of the outlet of the inner hydrogen injection conduit;

the cavity length being a value so that a ratio of the length to the depth is between 1 and 4;

the cavity trailing edge distance being a value so that a ratio of the cavity trailing edge distance to the diameter is no more than 5.

6. The method of claim 1, comprising:

generating a swirl of air via at least one swirler to generate a swirling flow for the mixture of air and fuel prior to outputting the mixture of air and fuel from the outlet of the outer conduit; and

passing the swirling flow within the combustion chamber to a position at which the mixture of fuel and air within the swirling flow crosses a discharge region of the outlet of the inner hydrogen injection conduit within the combustion chamber;

wherein the at least one jet of hydrogen is injected into a secondary wake region within the combustion chamber that is downstream of the outlet of the inner hydrogen injection conduit and upstream of the position within the combustion chamber at which the mixture of fuel and air within the swirling flow crosses the discharge region of the outlet of the inner hydrogen injection conduit; and

wherein the secondary wake region is between the outlet of the inner hydrogen injection conduit and the position within the combustion chamber at which the mixture of

fuel and air within the swirling flow crosses the discharge region of the outlet of the inner hydrogen injection conduit, the secondary wake region having at least one second wake that interacts with at least one first wake within a first wake region generated by the swirling flow of the mixture of air and fuel as the fuel combusts inside the combustion chamber.

7. The method of claim 6, wherein activated gas from combustion of fuel in the at least one first wake communicates heat and active chemical species with the at least one second wake.

8. The method of claim 1, wherein the at least one jet of hydrogen is at least one central jet of hydrogen and the outlet of the inner hydrogen injection conduit includes a nozzle with at least one central orifice to form the at least one central jet of hydrogen to inject hydrogen into the combustion chamber and multiple outer orifices to form multiple non-central jets of hydrogen to inject hydrogen into the combustion chamber, the method also comprising:

injecting the non-central jets of hydrogen into the combustion chamber via the outer orifices of the nozzle.

9. The method of claim 8, wherein the outer orifices are configured so that each of the non-central jets of hydrogen are output in a flow direction that flows at an angle to a flow direction of the at least one central jet of hydrogen, the angle being greater than 0° and less than 90° or greater than 15° and less than 60°.

10. The method of claim 8, wherein the at least one central jet of hydrogen has a velocity of at least 100 m/s and each of the non-central jets of hydrogen have a velocity that is at least 100 m/s.

11. The method of claim 1, wherein the at least one jet of hydrogen has a velocity of at least 100 m/s.

12. A method of injecting hydrogen into a combustion chamber of a combustor of a gas turbine system, the method comprising:

outputting a mixture of fuel and air into the combustion chamber via an outlet of an outer conduit in fluid communication with the combustion chamber to generate a first wake region; and

injecting at least one jet of hydrogen into the combustion chamber toward the first wake region via an outlet of an inner hydrogen injection conduit that is in fluid communication with the combustion chamber;

the outer conduit being positioned such that the outlet of the outer conduit is around an outer periphery of the outlet of the inner hydrogen injection conduit;

wherein the first wake region is downstream of the outlet of the inner hydrogen injection conduit and upstream of a position within the combustion chamber at which the mixture of fuel and air output from the outlet of the outer conduit crosses a discharge region of the outlet of the inner hydrogen injection conduit within the combustion chamber;

wherein a burner of the combustor includes the outer conduit and the injecting of the at least one jet of hydrogen into the combustion chamber via the outlet of the inner hydrogen injection conduit is performed to control operation of the gas turbine so that operation of the combustor of the gas turbine system is constrained by:

$$mH2, total < \left(\frac{\beta prim}{\beta H2}\right) * m, air * \left(\frac{MH2}{Mprim}\right) * (PFR0 - PFR1)$$

where:

mH2,total is a total hydrogen injection rate;

βprim is a molar, air-fuel stoichiometric coefficient for the fuel;

βH2, is a molar, air-fuel stoichiometric coefficient for hydrogen;

m,air is a mass flow rate of air;

MH2 is a molecular weight of hydrogen;

Mprim is a molecular weight of the fuel;

PFR0 is a fuel to air mass flow ratio prior to hydrogen injection; and

PFR1 is a fuel to air mass flow ratio during hydrogen injection.